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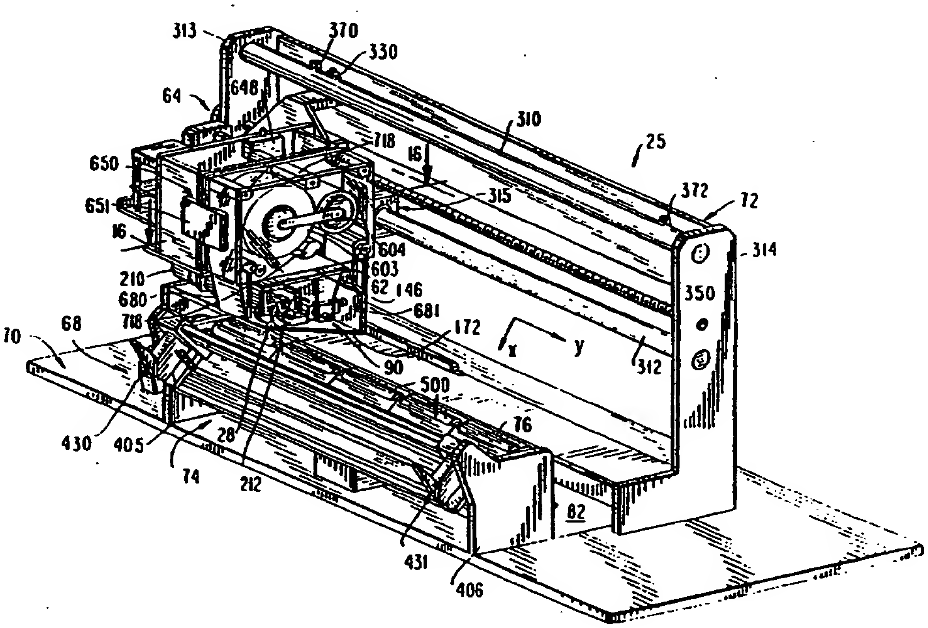
(57) Abstract

A novel thermal "strip mode" printing method and apparatus are disclosed. Data representing the image (26) to be printed is arranged in a plurality of X-axis strips (34-38) each having a Y-axis width substantially less than the width of the medium (27) to be printed on, i.e., each strip is substantially less in width than the width of the medium (27) to be printed upon so that a number of strips are necessary to print across the full width of the medium. Each strip may have a Y-axis width of from about 1 inch to about 4 inches. The strip mode thermal print head (28) is moved to an X-axis strip, then the medium (27) is moved to print in the strip. The strip mode print head (28) remains stationary while the medium (27) is moved to print an entire strip. The strip mode print head is next moved to print in another strip and held stationary while that strip is printed. Also disclosed are a Y-axis drive system (64) for moving the print head (28) and accurately positioning it in the strips (34-38), a stationary platen (76) having a resilient contact surface (280) supported on a rigid base (282) which has excellent straightness, and support for the print head which rotates about a pitch axis parallel to the Y-axis and about a roll axis.



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THERMAL STRIP MODE PRINTER COMPONENTS AND SUBASSEMBLIES

RELATED APPLICATIONS

Th printing and plotting apparatus disclosed herein employs or may employ some or all of the subject matter disclosed in the below-identified, commonly-owned U.S. patent applications. Serial No. 07/920,186, filed on even date herewith, entitled "Strip Mode Printing And Plotting Apparatus And Method (attorney docket HID-117); Serial No. 07/920,116, filed on even date herewith, titled "Ribbon Cassette Storage And Transfer Apparatus For A Printer" (attorney docket No. HID-185); Serial No. 07/920,117, filed on even date herewith, titled "Method And Apparatus For Gauging Reel Diameters In A Reel-To-Reel Sheet Material Transport System" (attorney docket No. HID-186); Serial No. 07/920,115, filed on even date herewith, titled "Sheet Medium Transport Systems Particularly For Printers And Plotters" (attorney docket No. HID-181/182). The disclosures of all of the patent applications identified above are incorporated herein by reference.

BACKGROUND OF THE INVENTION

The invention disclosed herein relates to methods and apparatus for operating a printer to print images and indicia (collectively referred to as "images"). More particularly, the invention disclosed herein relates to methods and apparatus for operating a thermal printer, particularly in a novel "strip" mode of printing which is different from line mode printing, serial (or raster scan) mode printing and vector mode plotting. The invention finds particular application in a thermal strip mode printer for printing graphic images, particularly in color and of wide format (e.g., wider than about 11 inches (about 28 cm)).

Modern color and monochrome computer or digital printing apparatuses are of the matrix type which typically print in line mode or serial mode an overall image on a sheet medium in small dots or other small geometric

configurations. A number of impact and non-impact technologies may be used for matrix printing in line mode or serial mode including impact wire- or pin-dot, thermal (direct and thermal transfer), ink jet and electrostatic. However, the invention disclosed herein is concerned with matrix thermal printers particularly for printing wide formate images (e.g., wider than about 11 inches (about 28 cm)), particularly in color. Because of the problems and/or drawbacks described below which would be encountered in attempting to adapt known line mode matrix thermal printer technology and known serial mode matrix thermal printer technology to wide format printing, the invention provides a novel strip mode of matrix thermal printing, which is different from both serial mode matrix printing and line mode matrix printing. A discussion follows of thermal printing and the problems and drawbacks of attempting to adapt serial mode matrix thermal printers and line mode matrix thermal printers to wide format printing. Vector mode plotters and problems and drawbacks associated therewith for wide format color plotting are also discussed below.

Matrix thermal printers may be of the direct type in which the print head directly contacts the sheet medium and directly forms dots on the sheet medium, or of the transfer type in which a thermally-activated donor transfer medium containing pigment, wax, resin, ink, etc. (hereinafter referred to as "ink") is interposed between the print head and the receptor medium, and a thermal print head contacts the donor or transfer medium to cause "ink" to be transferred in dots from the donor or transfer medium to the receptor medium. The thermal donor or transfer medium may be any conventional film having a heat activated "ink" layer. For simplicity, such a donor or transfer medium shall be referred to as a "ribbon". The receptor medium may be any suitable medium such as paper, plastic, mylar, etc.

Line m d matrix printers print an entire line at a time. By conventi n, th line or scan directi n, usually the width direction of the medium being printed up, is referred to as the Y-axis or Y-direction, and the direction orthogonal thereto, i.e., the length or feed direction of the medium, is referred to as the X-axis or X-direction. Line mode printers utilize a so-called full width print head having a width at least equal to the width of the medium on which the image is to be printed and print one full line of image in each relative position of the print head and the medium. Typically the print head in a line mode printer remains stationary at all times, and after or while each line is printed the medium is moved relative to the print head parallel to the X-axis in the length direction of the medium. (However, since relative motion is required, the print head may be moved parallel to the X-axis relative to a stationary medium, or both the medium and the print head may be moved in opposite directions parallel to the X-axis.) Thus, line mode printers relatively move the print head and the medium being printed upon in only one direction (parallel to the X-axis) to relatively move the print head and the medium to print one line of the image at a time.

Serial mode matrix printers (or raster scan printers) print the dots in desired locations serially along a line as the print head is moved or scanned parallel to the Y-axis. Serial mode matrix printers utilize a so-called flying or scanning print head having a length (Y-axis dimension) substantially less than the width of the sheet medium on which the image is to be printed and a width (X-axis dimension) a number of dots wide, e.g., tens of dots wide. The flying print head serially prints as the print head is continuously moved or scanned in the line parallel to the Y-axis. After each line is printed, the sheet medium is moved relative to the print head parallel to the X-axis. Thus, serial mode printers relatively move the print head and the

sheet medium in two directions. Typically the print head is moved parallel to the Y-axis and the medium is moved parallel to the X-axis, although in flat bed type printers, the medium is stationary and the print head is moved parallel to both the X- and Y-axes.

Each line of an image printed in line mode or serial mode is typically tens of dots wide (X-axis dimension), the exact number depending on the particular print head. U.S. Pat. Nos. 4,870,428 (Kuwabara et al.) and 4,688,050 (Tsao) disclose examples of a serial thermal printer with a print head a number of dots in width (X-axis), specifically, the thermal print head has a plurality of heating elements aligned in a column parallel to the X-axis.

Examples of thermal line mode printers are disclosed in U.S. Pat. Nos. 4,843,408 (Tanaka); 4,707,703 (Toida et al.); 4,542,997 (Matsushima); 4,540,992 (Moteki et al.); 4,447,818 (Kurata et al.); and 4,067,017 (Dertouzos et al.).

Examples of thermal serial mode printers are disclosed in U.S. Pat. Nos.: 5,063,392 (Carr et al.) (pin dot matrix or thermal, color); 4,940,994 (Habelt et al.); the '428 Kuwabara et al. patent referenced above; 4,844,632 (Minowa); 4,809,018 (Nakamura et al.); 4,789,873 (Matsuura); 4,750,007 (Suzuki); 4,712,115 (Tatsumi et al.); 4,694,305 (Shiomi et al.); 4,692,774 (Nagashima et al.); the Tsao '050 patent referenced above; 4,647,232 (Costa); 4,575,733 (Hattori et al.); 4,563,692 (Negita et al.); 4,517,573 (Yana); and 4,070,680 (Shelley). U.S. Pat. No. 4,403,874 (Payne et al.) discloses a color printer having a number of print heads and a single ribbon cartridge containing a separate ribbon for each print head. The print heads and the cartridge are all mounted to the same carriage which is moved in serial mode in order to print across the width of the sheet medium in different colors.

In vector mode plotting, the image is converted into a series of vectors, and the print head and the medium are

relatively moved simultaneously in two orthogonal directions (parallel to the X- and Y-axes) to plot each of the vect rs. Vector plotters typically use marking devices such as pens, although ink jet vector plotters have been proposed at least in the patent literature.

Examples of vector mode plotters are disclosed in U.S. Pat. Nos. 4,794,403 (Sieber et al.) (flat bed, pen type, color); 4,621,273 (Anderson) (ink jet); 4,554,556 (Hirata et al) (ink jet, color); 4,888,710 (Venthem et al) (pen type); 4,734,716 (Silverberg et al.) (pen type); 4,547,968 (Peterson) (pen type, color); the '680 Shelley patent referenced above (thermal); 3,968,498 (Uchiyama) (flat bed, ink jet).

As mentioned above, problems and/or drawbacks in applying or using line mode and serial mode printing and vector plotting technologies for printing or plotting wide format full color images prompted the research which led to the strip mode matrix printing invention disclosed herein. Such problems and drawbacks relate primarily to mounting, positioning and controlling the thermal transfer ribbon, mounting the print head and the construction of the platen. Additionally, cost was a factor which mitigated against adopting possible solutions to certain problems.

During thermal transfer printing, the thermal elements in the print head contact the thermal transfer ribbon and press the ribbon against the sheet medium which is supported by a platen. By heat and some pressure the print head activates and transfers the ink carried by the ribbon onto the sheet medium. The ribbon and the sheet medium are maintained in contact and heat is applied by the print head for a predetermined minimum "dwell" time sufficient to effect transfer of ink to the receptor sheet medium. In line mode printing, the medium is typically continuously moved past the print head at a rate slow enough to permit the print head to heat and press the ribbon against the

sheet medium for at least the minimum required dwell time, and in serial mode printing, the print head is moved continuously along the medium at such a rate. Typically, the thermal transfer ribbon becomes temporarily adhered to the receptor sheet medium during the dwell time as the ink layer is melted and the ink is transferred to the sheet medium so that movement of the sheet medium also initially moves with it the thermal transfer ribbon and then effects separation of the two.

To accommodate this movement of the transfer ribbon and the medium in a line mode printer, the thermal transfer ribbon supply and take-up reels would have to be arranged with their axes parallel to the Y-axis on opposite sides of the print head with the ribbon spanning the full width of the medium. This arrangement of the transfer ribbon presents a problem for wide format, line mode printing because it is difficult to position the ribbon supply and take-up reels, and it is difficult, and likely presently impossible within the state of the art, to move and control the transfer ribbon across its full width for the full, wide span of the ribbon across the full width of the medium. The cost such wide ribbons would also be expensive.

Ribbon control presents further problems for a line mode color, thermal transfer printer because the design task of moving the different colored wide format ribbons into and out of a printing position adjacent a common print head, or moving the common print head to the ribbons, would be extremely difficult and complicated. Additionally, the need in full color printing to provide a number of wide transfer ribbons of different colors, or a single multi-colored wide transfer ribbon becomes quite expensive. Although use of a single multi-colored wide transfer ribbon would avoid the problem of having to move long spans of ribbons into and out of a printing position adjacent the print head (and/or having to move the print head), there are drawbacks to using

such multi-colored ribbons, particularly wide ones. First, multi-colored ribbons ar exp nsive. Also, sinc prior art printers index the entire multi-colored ribbon during printing so that the portions of the ribbon having the colors not then being printed are simply indexed past the print head without being used. Either those unused portions are not used at all, which is wasteful, may require frequent ribbon reloading and may be quite expensive due to high ribbon cost, or the ribbon has to be indexed back to those unused portions for later use, which requires a means to identify unused portions of the ribbon and the color of such unused portions, and a bi-directional indexing means.

Line mode, thermal transfer printers use a platen which is as long as the width of the medium and as wide as the width of the print head. To obtain a uniform optical density of a relatively wide image being printed, a uniform contact pressure, as low-as-possible to reduce frictional drag between the sheet medium and the print head and any intervening thermal transfer ribbon, must be maintained between the print head and the platen over the entire printing length of the platen. To obtain such a uniform, low-as-possible contact pressure, the distance between the print head and the platen must be kept uniform since variations in that distance could show up as variations in print quality. Since the platen is two dimensional, i.e., has a significant X dimension to accommodate a print head having tens of thermal elements extending in the X-direction, and a Y dimension which is as long as the media is wide, it becomes expensive and difficult, if at all possible with current manufacturing practices, to maintain tolerable variations in alignment and/or spacing of the print head and the platen.

Serial mode printers would avoid the ribbon control problems discussed above that line mode printers would have in wide format thermal transfer printing because, as pointed

out above, serial mode printer utilize a very narrow print head in the line direction (Y-axis), typically one or only a few thermal elements long, e.g., about 0.025 inch or 0.64 mm for a linear, single thermal element wide array, but typically tens of thermal elements in width (X-direction) e.g., about 0.2 inch or 5 mm. However, like line mode thermal transfer printers, serial mode thermal transfer printers use a platen which is as long as the width of the medium to be printed upon, and as wide as the print head, and therefore would have the same problems as line mode printers with respect to variations in the distance between the print head and the platen.

Another problem in attempting to apply known thermal transfer printer technology to wide format printing is the difficulty in mounting the thermal print head with respect to conventional platens so that the thermal elements may contact the thermal transfer ribbon and press it against the sheet medium and the platen (or directly contact the sheet medium) while at the same time maintaining the uniform distance between the thermal elements and the platen as discussed above. The bottom of most if not all currently available thermal print heads is not flat, and the thermal elements are mounted to the bottom of the print head near one edge spaced from a protruding part of the print head. As a result, it is typically necessary to mount the print head at an angle to the platen contact surface of a flat platen to avoid contact of the bottom of the print head with the platen, or to use a roller type platen. It is extremely difficult to so mount one or more thermal print heads adjacent a flat platen for wide format printing, and it is extremely difficult to maintain a uniform distance between a long print head (or a number of shorter adjacent print heads) and a single long roller platen.

Vector mode plotters for full color plotting also have problems. Since each line of the image is vector plotted,

the sheet medium must make a large number of passes in both directions past the print head to plot all th vect rs. Since very accurate registrations of the sheet medium and plot head must be maintained in order to provide an accurate plot, the drive for the sheet medium tends to grip it tightly, and in typical applications makes indentations or perforations in the sheet medium which register with the structure that made them in the nature of a sprocket wheel drive. However, with the large number of passes required for a complex plot, or for a color plot, there is the possibility of a loss of registration between the sheet medium and its drive as the number of passes increases, and there is the tendency for the drive to tear the sheet medium. Also, vector mode plotting particularly in color and for larger size and relatively complex plots is very slow compared to line and serial mode matrix printing. However, the quality of a vector mode plot is generally better than a line mode or serial mode printed plot for equipment of comparable cost.

There is a need for apparatus and methods for printing (or plotting) graphic images, and for operating printers, which do not have the problems described above associated with full width line mode matrix printers, serial mode matrix printers and vector mode plotters, while providing high quality monochrome and color prints or plots of both simple and complex images for both narrow and wide images.

SUMMARY OF THE INVENTION

It is an object of the invention disclosed herein to provide improved methods and apparatus for moving a print head.

It is another object of the invention to provide improved apparatus for supporting a movable print head.

It is another object of the invention to provide improved platens for printers.

Thermal printing according to a new strip mode of

matrix printing which is different from line mode matrix printing and serial mode matrix printing. According to strip mode printing, the image is printed neither serially nor an entire line at a time, although strip mode printing utilizes attributes of both serial and line mode printing, but without the disadvantages discussed herein of either. Printing in the new strip mode overcomes the problems and disadvantages discussed above with line mode and serial mode thermal printers and vector mode plotters for wide format monochrome matrix printing, and also for wide format matrix color printing.

The invention of strip mode printing which is described herein stemmed from a recognition of the problems discussed above in relation to wide format thermal printing and wide format thermal color printing, namely the problems relating to maintaining the alignment and spacing between the thermal print head and the platen and the mounting of the thermal print head or heads, and the problems of mounting and controlling the thermal transfer ribbons, and the recognition that these problems could be overcome as disclosed herein. The particular recognition that it was easier to control tolerances in one dimension rather than two led to investigation of extremely narrow platen contact surfaces and print head mountings compatible therewith.

Thermal strip mode printing utilizes a thermal print head in which a plurality of thermal elements are arranged in an elongated narrow array having an overall length and an overall narrow width, the length being larger than the width. The narrow width of the array is arranged parallel to the X-axis, and the longer length of the array is arranged parallel to the Y-axis. As a result the "X" dimension of the platen contact surface may be made extremely narrow. "X-axis" and "Y-axis" have the conventional meanings in plotters and printers. The image to be printed is separated into strips having a width up to the length of the thermal

array, and each strip is separated into lines. In the preferred embodiments, th image is printed strip-by-strip, that is all lines of a strip are printed, then the print head is positioned to print in another strip.

The medium to be printed upon has a first dimension parallel to a first axis and a second dimension parallel to a second axis. In typical printers and plotters, the first axis is the Y-axis of an X-Y coordinate system and the second axis is the X-axis of the X-Y coordinate system. The length and width of the thermal array are substantially less than the first and second dimensions of the medium, respectively, and, in accordance with the invention, the length of the thermal array extends parallel to the first axis (Y-axis), as opposed to extending parallel to the second axis (X-axis) as in serial mode printers.

For example, the thermal print head as oriented in accordance with the invention has a very narrow width (parallel to the X-axis) of only one or a few thermal elements wide (e.g., 0.025 inch (about 0.64 mm)) and a longer length (parallel to the Y-axis) (e.g., about 1 inch (about 2.5 cm) to about 4 inches (about 10 cm)). Correspondingly, the maximum width of the strips which are printed in strip mode printing according to the preferred embodiments of the invention are up to about four inches (about 10 cm). The contact surface of the platen against which the print head, transfer ribbon (if one is used) and medium bear is thus rendered substantially one-dimensional, which facilitates maintaining it essentially flat over a long distance. Mounting the thermal print head with the thermal elements extending parallel to the platen length (Y-axis) and which is yet relatively short in the Y-direction (e.g., about 1 to 4 inches), solved the problem discussed above of maintaining a uniform distance between the print head and the platen over a relatively long Y-axis distance, and greatly facilitated print head mounting.

Also, making the print head relatively short in length (X-axis) compared to the width of the medium to be printed upon enables relatively narrow width transfer ribbons to be employed. Further, mounting the print head with the thermal elements extending parallel to the Y-axis enables the transfer ribbon to be mounted with the axes of the supply and take-up reels parallel to the Y-axis, thereby avoiding the disadvantages discussed above associated with the control and mounting of wide transfer ribbons.

In strip mode printing, data representing the image to be printed is arranged into a plurality of strips each having a length parallel to the first axis (X-axis) of the medium to be printed upon. The Y-axis length of the strips is less than or equal to the length of the thermal array of the thermal print head, i.e., up to about 4 inches (about 10cm) as described above. At least one of the strips has a length equal to the length of the thermal array. The data representing each strip of the image to be printed is arranged into a plurality of lines each having a width parallel to the second axis (X-axis) of the medium equal to the width of the thermal array and a length parallel to the first axis (Y-axis) up to the length of the strip.

The print head and the medium are relatively moved to relatively position the print head adjacent a desired location of the medium corresponding to a strip to be printed. The print head is caused to thermally print respective lines of the image in respective strips of the image. For example, a first line of the image is printed in a first strip of the image at the desired location, and the print head and the medium are repeatedly relatively moved to relatively position the print head adjacent the medium at other locations of the medium in which other lines of the image are to be printed, and the print head is caused to print respective other lines of the image on the medium in respective other locations of the sheet medium until the

image is printed.

In order to print across the full width of a given size medium, it may be necessary to print one or more strips of partial length, i.e., strips having a length less than the overall length of the thermal array, which would typically be printed adjacent the edge or edges of the medium.

In the preferred method and apparatus for strip mode printing, for both monochrome and color thermal strip mode printing, the image is printed strip by strip, i.e., the print head and sheet medium are relatively moved to position the print head in a given strip, then the print head and the sheet medium are relatively moved to print all lines of that strip, and then the print head and the sheet medium are relatively moved to position the print head in another strip, etc. Also, the print head is moved parallel to the first axis (Y-axis) relative to the medium to be printed upon to relatively position the print head in a desired strip, and the medium is moved parallel to the second axis (X-axis) relative to the print head to relatively position.

Preferably, a thermal transfer medium or ribbon is provided and printing is accomplished by causing the print head to transfer the "ink" from the ribbon to the receptor medium. To conserve ribbon, the ribbon is only advanced past the print head from a supply thereof when the print head is in an active printing position.

With respect to thermal color printing which requires different colored ribbons or ribbon portions, strip mode printing lends itself to the use of multiple, different colored ribbons for several reasons. The length which the ribbons must span are relatively narrow, i.e., approximately only the width of a strip (up to about four inches). Because transfer ribbon reels are positioned for printing with their axes parallel to the Y-axis, the cassettes or cartridges housing the transfer ribbons may be stored and exchanged from a side of the print head where it is easier to make

space available. This also permits a carriage to which the print head is mounted to be moved along the same Y-axis path in which it is moved for printing to effect transfer of a cassette between the carriage and a storage station located in or adjacent the carriage path of travel due solely to carriage motion.

A method of matrix printing a color image arranges the data representing the image to be printed not only into a plurality of strips and lines as described above, but also separates the image to be printed into two or more colors such that thermally printing respective parts of the image in respective colors of the separated colors prints the color image. A thermal print head is used and oriented as described above. While a multi-colored thermal ribbon having a plurality of portions of different color may be used, preferably a plurality of different colored thermal ribbons is used. The print head is oriented relative to the medium to be printed upon as described above with the length of the thermal array extending parallel to the first axis (Y-axis). The print head is caused to thermally print selected lines of the image in a selected color or colors from the multi-colored ribbon or a selected one of the plurality of different colored ribbons to print the color image.

Apparatus for matrix strip mode printing an image on a medium to be printed upon comprises the thermal print head described above oriented relative to the medium as described above, means for relatively moving the print head and the medium parallel to the first axis (Y-axis) to position the print head in each of a plurality of strips and for relatively moving the print head and the medium parallel to the second axis (X-axis) to selectively position the print head adjacent each of a plurality of lines in the strips, and means for causing the thermal print head to thermally print in selected lines in the strips, when the print head

is adjacent the respective line, that respective part of the image which is to be printed in that respective line.

Apparatus for matrix printing a color image on a medium to be printed upon comprises the apparatus described above for matrix printing an image and a multi-colored thermal transfer ribbon having a plurality of portions of different color or preferably a plurality of different colored thermal transfer ribbons, and means for separating the color image to be printed into two or more colors such that thermally printing respective parts of the image in respective colors of the separated colors prints the color image.

In the preferred method and apparatus of thermal matrix color strip mode printing, a plurality of thermal transfer ribbons of different color are used, and the print head is caused to thermally print selected lines of the image in a first color from a first thermal transfer ribbon to print all lines of the image in the first color, and then the print head is caused to thermally print selected lines of the image in other colors from other thermal transfer ribbons to print all lines of the image in all colors, color by color. Providing separate ribbons for different colors is preferred because it has the advantages over a single multi-color ribbon of conserving ribbon during printing, particularly when printing in a single color, and the possibility of printing in a wider variety of colors and in specialty colors.

In the preferred embodiments of strip mode printing, the print head is moved to a non-printing position spaced from the medium to be printed upon when the print head is not printing, and the print head and the medium are relatively moved but the transfer ribbon is not moved when the print head is in the non-printing position.

Where a plurality of thermally-activated transfer ribbons are used, a given transfer ribbon is automatically transferred from a storage station into a printing position

relative to the thermal print head in response to a given condition, which may be detection of little or no unused ribbon present on the supply reel of the ribbon then being used, or the completion of printing in a given color.

Structure is provided for reducing the drag on the medium being printed upon as it progresses downstream (the positive "X" direction) from the print head, and for maintaining accurate registration of the medium.

As mentioned above, a problem to be overcome was maintaining a given spacing between the print head and the platen. The solution disclosed herein for obtaining low variations in the distance between the thermal print elements and the platen contact surface utilizes a stationary platen having a relatively narrow, resilient contact surface, as opposed to a rotating drum platen. It was found that variations in the height (i.e., flatness or straightness) of such a stationary platen over the full printing width may be maintained low in a relatively simple manner at a relatively low cost. Any variations in the distance between the platen contact surface and the thermal print elements are accommodated by spring loading the thermal print head towards the platen with freedom to pivot about a pitch axis (parallel to the Y-axis) and about a roll axis (parallel to the X-axis), and by making the platen contact surface resilient. The contact surface is sufficiently resilient to yield a sufficient amount under a given minimum spring pressure applied to the print head to cause the print head thermal elements to contact the thermal transfer medium and force the thermal transfer medium and the medium to be printed upon against the platen with a uniform contact pressure over the full width of the array of thermal print elements and the full length of the platen.

A platen according to the invention for use in a thermal printing apparatus extends in the first direction referred to above, e.g., the Y-direction. The print head is

movable relative to the medium to be printed upon and the platen in the first direction. The print head is urged against the platen and any intervening medium to be printed upon and any intervening transfer medium. The platen comprises a rigid support element having a length (Y-axis dimension) at least twice as long as the width (X-axis dimension) of the thermal element array in the print head. Typically, the length of the platen is greater than 11 inches. The platen further comprises a resilient substrate element supported by the rigid support element for substantially all of the length of the support element. In one embodiment, the substrate element has flat sides which are exposed relative to the support element. The flat sides of the substrate element meet at a flat top of the substrate element which defines the width of the contact surface which is only about twice as wide as the width (X-direction dimension) of the thermal print elements in order to reduce the magnitude of the contact force required (a wider contact surface results in wider distribution of the contact pressure, which requires a higher contact force). In practice, however, the width of the substrate element top is less than about twice the width of the thermal print elements, e.g., about 0.050 inch (about 1.28 mm). A thin, wear resistant, low friction, flexible contact element, e.g., a film, adjacent the top of the flat exposed top of the resilient substrate element is supported thereon so as to cooperate with the resilient substrate element to provide a wear resistant, low friction flexible contact surface against which the print head, the medium to be printed upon and any intervening transfer medium may act upon.

The platen rigid support element is elongated and has a top extending for substantially all of the length of the support element. The top is of a width which is slightly larger than the width of the top of the flat exposed top of the substrate element. A groove extends in the support

element top in which is received the substrate element with the top thereof exposed. The rigid support element has opposed sides spaced apart by a width larger than the width of the top thereof. A transition region extends between at least one side of the rigid support element and the top thereof in which the support element tapers to the top thereof. Preferably, the support element top is generally centered relative to the sides and such transition region extends between each side of the rigid support element and the support element top. The opposed transition regions of the support element each have outer surfaces which each form an angle with the sides of the rigid support member, e.g., 45°.

The substrate element in one embodiment has a base wider than the top thereof and a transition region between at least one side of the base and the substrate element top in which the substrate element tapers between the at least one side of the base and the substrate element top. Preferably, the substrate element has a base wider than and centered relative to the top thereof and a transition region which extends between each side of the base and the substrate top, with the substrate top projecting from the support element top. The transition region of the substrate element has outer side surfaces which each form the same angle with the sides of the substrate element as do the transition regions of the rigid support element with the sides of the support element, and are flush with the transition surfaces of the rigid support member.

In another embodiment, the top of the support element is curved and the resilient substrate element is fitted, molded or cast over and conforms to the curved top of the support element.

Unlike a rotating drum platen, a stationary platen introduces frictional drag on the medium being printed upon in the area of contact of the thermal print elements

(through the thermal transfer medium). Such drag is undesirable for the reasons discussed below. To reduce such drag to an acceptable level, the contact surface of the platen is made of a wear resistant, low friction material, as mentioned above. Flexibility of the contact surface is obtained by making the contact surface material itself thin and underlying it with a resilient material, as mentioned above. The thin, flexible contact element may be a film as described below. The film may be attached to opposed sides of the rigid support element extending over the substrate element, or adhered to the substrate element by bonding thereto, or deposition thereon, etc., or by both attachment and bonding, etc.

The thermal print head is supported in accordance with the invention and resiliently urged against the platen with a given contact force upon any intervening medium to be printed upon and any intervening transfer medium, and with two degrees of freedom - pitch and roll- without cross-coupling therebetween. The print head is supported resiliently biased for pivoting a sufficient amount about a pitch axis parallel to length or X-direction of the media to accommodate small variations in the flatness or straightness of the platen so that such variations in the flatness or straightness of the platen do not visibly affect print quality. The print head is also supported resiliently-biased for pivoting about a roll axis normal to the pitch axis and parallel to the width or Y-direction of the media. The print head is also supported for pivoting a sufficient amount about the roll axis to space the print head a given distance from the platen (e.g., in the Z-direction) to permit relative movement between the print head and the medium adjacent the platen in a non-printing position of the print head.

The print head support comprises a roll axis gimbal element and means for attaching the print head thereto for

rotation of the print head about the roll axis while resiliently urging the print head against the platen relative to the roll axis and any intervening medium to be printed upon and any intervening transfer medium. The print head support also comprises a pitch axis gimbal element and means for attaching the roll axis gimbal element and the pitch axis gimbal element for rotation of the roll axis gimbal element about the pitch axis while resiliently urging the roll axis gimbal element towards the platen and resiliently urging the print head against the platen. Means are provided for moving the print head in the Z-direction and for holding it a given distance from the platen in a non-printing position thereof. In addition to providing for two degrees of freedom of the print head, the print head support described above eliminates cross-coupling from one axis to the other.

A drive system (Y-axis drive system) is coupled to the print head to move it in the width (Y-direction). It is important that the edges of each printed strip match exactly, i.e., no conflicting overlap and no unwanted spaces. To accomplish that, a precision Y-axis drive system is provided in accordance with the invention at relatively low cost, of relatively simple construction and essentially without hysteresis, backlash, and component tolerance errors. In accordance with the invention, such a drive system includes a plurality of gear, pulley or like elements which are configured and coupled so that the absolute angular position of each such element is precisely the same for each relative position of the print head and the medium to be printed upon in each of the strips.

The preferred embodiment of the Y-axis drive system for moving the print head comprises a lead screw and associated lead nut, means rotatably supporting the lead screw parallel to the width of the media, means for supporting the print head coupled to but substantially unsupported by the lead

scr w for movement in the width direction along the lead screw, means coupling the lead screw and the print head to move the print head in the first direction upon rotation of the lead screw, and means coupled to the lead screw for rotating the lead screw. The means for rotating the lead screw comprises a motor and means coupling the motor to the lead screw. The means coupling the motor to the lead screw, and the lead screw are configured to position the motor, the means coupling the motor to the lead screw and the lead screw in exactly the same angular position for each position of the print head in the width direction.

Although the effects of pitch errors in the lead screw are not eliminated, lead screws and associated lead nuts may be manufactured to relatively close tolerances, e.g., 0.0002 inch/inch, which tolerances essentially do not affect the accuracy of 300-400 DPI prints. Moreover, since the lead screw need be indexed only a relatively small number of times corresponding to the number of strips and passes referred to above, lead screw errors have a negligible effect on print accuracy.

The means supporting the print head comprises first and second bars along which the print head may be displaced substantially without loading the lead screw. The first bar extends parallel to the lead screw. A member attached to the print head has an opening therethrough corresponding in cross section to the cross section of the bar through which the bar passes in a supporting relationship with the print head such that the print head may be displaced along a longitudinal axis of the first bar and be pivoted relative to the longitudinal axis of the first bar. The second bar extends parallel to the lead screw and parallel to the first bar and is positioned to restrain the print head from pivoting relative to the first bar while permitting the print head to be displaced along the longitudinal axis of the second bar.

The Y-axis drive system described above provides simplified mechanical adjustment and alignment and excellent accuracy for multiple passes of the print head relative to the medium to be printed upon at relatively low cost.

The print head (and its support) are mounted to a carriage which is moved parallel to the first axis (Y-axis) by the Y-axis drive system. Also mounted to the carriage is a part of the printer controller which includes elements for controlling the functions performed by elements mounted to the carriage, including heating of the print head thermal elements, raising and lowering of the print head and control of the transfer ribbon. Locating such components on the moving carriage reduces the number of connections needed to the carriage, and greatly reduces interference and noise which otherwise may have been introduced into the system through a large number of interconnecting cables. With so few connections, it is feasible to use coaxial shielded cables for the connections.

Media of different types may be printed upon in accordance with the invention. Typically, such media will be sheet media of the type referred to herein. Reference herein to sheet media or sheet medium is not meant to be limiting and refers to media of different types which may be printed upon in accordance with the invention.

ADVANTAGES OF STRIP MODE PRINTING

Strip mode matrix printing provides wide format, monochrome and full color, graphic images of excellent quality at printing speeds comparable to line and serial mode matrix printers and substantially greater than the speeds of vector mode plotters.

More specifically, the strip mode printer disclosed herein provides a number of advantages over line mode and serial mode thermal matrix printers, including those pointed out above and the following. Strip mode printing in accordance with the invention provides almost as much

throughput as line or serial mode, yet at comparable cost because the accurate Y-axis driv (disclosed herein) needed for accurately positioning the print head in the strips is not much more expensive than a serial Y-axis drive, and is less expensive than the cost for the full width print head needed for a line mode printer. Strip mode printing will typically provide more uniform print distribution than a serial mode or a line mode thermal printer because the line width in strip mode is much narrower than that in serial or line mode so that errors between lines will tend to be smaller and be distributed evenly over the entire plot, rather than the larger errors concentrated only between adjacent edges of one wide line and the next. As to advantages over thermal color printers, strip mode thermal printing enables excellent quality, well registered, wide format color plots to be printed where serial mode and line mode printers cannot, for the reasons pointed out above. Because of strip mode printing, a cassette of relatively narrow ribbon may be positioned in the printing position thereof above the print head with the ribbon reel axes parallel to the Y-axis, which enables a number of cassettes to be stored as disclosed herein off to the side of the active printing area mounted so that they may easily be transferred from the carriage to a storage location and vice versa simply by moving a carriage to which the print head is mounted to the end of its travel. This feature of easy cassette storage and transfer which is made possible by thermal transfer strip mode printing provides a tremendous versatility in the possible colors that may be used, the printing sequences that may be run and the type of print media that may be used, all of which may be handled by software rather than hardware so that change and accommodation are easily implemented. The capability of using different ribbons for different colors also reduces cost as compared to a single multi-colored ribbon for the

reasons stated above.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is illustrated in the figures of the accompanying drawings which are meant to be exemplary and not limiting, in which like references refer to like or corresponding parts, and in which:

Fig. 1 is a perspective view from the left side of thermal printing apparatus according to the invention for printing images in strips in accordance with the invention, with the cabinet for the apparatus shown in broken lines, and without the supply roll of the medium to be printed upon, the medium hanger, the medium cutter and some interconnecting wiring;

Fig. 2 shows a completed full image printed by the apparatus of Fig. 1;

Figs. 3A-3E show parts of the image of Fig. 2 and illustrate the sequence for strip mode printing the image of Fig. 2;

Fig. 4 is a front perspective view from the right side of the thermal printing apparatus of Fig. 1 without the cabinet and without the ribbon cassette storage and transfer system;

Fig. 5 is a rear perspective view from the right side of the thermal printing apparatus depicted in Fig. 4;

Fig. 6 is an enlarged perspective view from the right side of a portion of the apparatus of Fig. 1 showing the thermal print head, a portion of the print head support, a portion of the platen, a portion of the sheet medium roll with a sheet therefrom passing between the print head and the platen, a portion of the transfer ribbon passing between the sheet medium and the print head, and a portion of the X-axis guide roller;

Fig. 7 is a rear perspective view from the left of the print head portion of the printing apparatus depicted in Fig. 1 showing the print head lowered in its printing

position;

Fig. 8 is a rear perspective view similar to that of Fig. 7 showing the print head in its raised, non-printing position;

Fig. 9 is a rear perspective view of the support structure for the print head depicted in Fig. 7;

Fig. 10 is a section view of the support structure and print head depicted in Figs. 7-9 taken along line 10-10 in Fig. 9;

Fig. 11 is a front perspective view from the right side of the print head portion of the printing apparatus depicted in Fig. 1 showing the print head raising mechanism with the print head in its lowered printing position;

Fig. 12 is a front perspective view similar to that of Fig. 11 with the print head in its raised, non-printing position;

Fig. 13 is a section view of the apparatus depicted in Fig. 1 taken along line 13-13 in Fig. 1;

Fig. 13A is an enlarged section view of the top portion of the platen shown in Fig. 13;

Fig. 13B is an enlarged section view similar to that of Fig. 13A of the top portion of an alternate embodiment of the platen;

Fig. 14 is a section view of the apparatus depicted in Fig. 1 taken along line 14-14 in Fig. 1;

Fig. 15 is an exploded perspective view of one of the X-axis guide rollers and its housing which form part of the X-axis drive system of the printing apparatus of Fig. 1;

Fig. 16 is a cross section view of the thermal transfer ribbon cassette and the ribbon drive system of the printing apparatus of Fig. 1 taken along line 16-16 of Fig. 4;

Fig. 17 is a schematic diagram of the printing apparatus of Fig. 1 showing three embodiments of systems for storing transfer ribbon cassettes and for moving a respective cassette between its storage position and its

printing position, and also showing a media cutter, a media hanger and a roll of the sheet medium to be print d upon;

Fig. 18 is an elevation view of the right side (cassette side) of the turret of the ribbon cassette storage and transfer system;

Fig. 19 is an elevation view of the left side (drive side) of the turret of the ribbon cassette storage and transfer system;

Fig. 20 is an elevation view of the front end of the turret of the ribbon cassette storage and transfer system;

Fig. 21A is a side view of portions of the print carriage and the turret showing the relative positions thereof at the start of a cassette transfer operation from the turret to the print carriage;

Fig. 21B is a side view similar to that of Fig. 21A showing the relative positions of the cassette mounting elements on the print carriage and the turret during a transfer operation;

Fig. 22 is a block diagram of the system controller for the printing apparatus of Fig. 1;

Fig. 23 is a data flow diagram which illustrates the data flow in the system controller of Fig. 22 according to the top level operating routine flow charted in Fig. 24;

Figs. 24-28 are flow charts which illustrate operation of the printing apparatus of Fig. 1, of which:

Fig. 23 is a flow chart of the top level operating routine;

Fig. 25 is a flow chart of the receive a plot sub-routine;

Fig. 26 is a flow chart of the parse plot data into drawing list sub-routine;

Fig. 27 is a flow chart of the rasterize drawing list into bit maps sub-routine; and

Fig. 28 is a flow chart of the print strip bit maps sub-routine.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Strip M de Printing/Th rmal Print H ad Orientati n

Plotting or printing apparatus 25 according to the invention (Fig. 1) prints an image 26 (Fig. 2) on a sheet medium 27 in the strip printing mode described above employing a thermal print head 28 (Figs. 4, 6, and 10-12). With reference to an X-Y coordinate system, by convention in the plotting art the Y-axis extends parallel to the line or scan direction, i.e., the width direction of the sheet medium 27, and the X-axis extends orthogonal thereto, i.e., in the length or feed direction of the sheet medium, as shown in the drawings. Sheet medium 27 may be paper, plastic, mylar, etc. Thermal print head 28 may be conventional in so far as the construction and operation of the thermal elements are concerned, but not in the manner in which the thermal elements are laid out relative to the axes of the printer.

Referring to Figs. 4 and 6 the size of print head 28 is substantially less in length (Y-axis) and width (X-axis) than the width (Y-axis) and length (X-axis) of the sheet medium 27. Referring to Fig. 10, thermal print head 28 comprises an array 29 of thermal elements 30 having an overall length "L" extending parallel to the Y-axis and an overall width "W" extending parallel to the X-axis. As pointed out above, print head 28 is oriented with respect to the X-Y coordinate system and with respect to sheet medium 27 with the elongated array 29 of thermal elements 30 extending parallel to the Y-axis and the width of sheet medium 27, which is different from the manner in which they are laid out in conventional matrix printers.

Referring to the image 26 and parts thereof shown in Figs. 2 and 3A-3E, in strip mode printing according to the invention print head 28 (not shown in Figs. 2 and 3A-3E) is moved parallel to the Y-axis to position print head 28 to print in strips 34-38, each having a width up to the length

"L" of array 29, and sheet medium 27 is moved parallel to the X-axis to position print head 28 to print in lines (not shown) each having a width equal to the width "W" of array 29. Depending upon the particular width of sheet medium 27 and the particular length "L" of array 29, printing apparatus 25 may print in one or more partial length strips 38 at either or both edges of sheet medium 27 in order to print on the full width of the media. In the sequence illustrated in Figs. 3A-3E, only one partial width strip 38 is printed.

The length "L" of each line of a strip printed by print head 28 for each X-axis position of print head 28 and sheet medium 27 is substantially less than the width of sheet medium 27, in contrast to a line printed by a full width, line mode print head which may extend for essentially the full width of the medium. Also, the length "L" of each line is much longer than the length of portions of an image printed by a serial print head for each relative Y-axis position of the print head and the medium, which is typically no more than one tenth of an inch long. The width of each line of an image printed by printing apparatus 25 in any strip is only one or a few elements wide in contrast to matrix serial printing where the width may be tens of thermal elements wide.

In the preferred embodiment, thermal array 29 (Fig. 10) is a linear array, one thermal element wide (X-axis) and 768 or 516 thermal elements long (Y-axis) at 12 or 16 per mm for 300 or 400 DPI printing, respectively. A typical thermal element 30 has a diameter of about 0.0025 inch (about 0.064 mm), and with its covering glass bead, a diameter of about 0.025 inch (about 0.64 mm). The length "L" of thermal array 29 is approximately 1.9 inches (48 mm) long and the width "W" is approximately 0.025 inch (about 0.64 mm) wide. The length "L" of array 29, however, may be in the rough range of about 1 inch (2.54 cm) to about 4 inches (102 cm).

Thermal array 29 may be linear (one thermal element wide) as presently preferred, or may be several thermal elements wide up to, at the current time, about 10 thermal elements wide, e.g., up to about 0.25 inch (about 6.4 mm) wide. The width of array 29 depends upon how flat the platen contact surface may be maintained. As the width of array 29 increases, it becomes more difficult to maintain the platen contact surface flat. The technology of the thermal print elements is conventional, and thermal print heads of the type described in this paragraph may be obtained from Kyocera Corp. of Kyoto, Japan. However, the location of the circuit terminations for thermal elements 30 of print head 28 is modified compared to conventional thermal print heads to facilitate mechanical mounting of print head 28. Thermal control of the thermal elements 30 is discussed below.

In the preferred embodiment, image 26 (Fig. 2) is printed strip-by-strip, i.e., all lines of image 26 defining a strip, e.g. strip 38, are printed before lines of another strip are printed. In the preferred embodiment for printing a color image, the image is printed strip-by-strip, one color at a time, i.e., all strips are printed in one color before any strip is printed in another color.

In the example of strip mode printing illustrated by Figs. 3A-3E, the sheet medium 27 is A size (shown reduced in the drawings) and there are four full length strips 34-37, each having a width of about 48 mm (about 1.9 inches), and one partial length strip 38 adjacent the left edge of sheet medium 27. Similarly, with a print head 28 having an array of the above dimensions, five full width strips and one partial width strip are needed for printing a B size drawing, eight full width strips and one partial width strip for a C size drawing, 11 full width strips and one partial width strip for a D size drawing and 16 full width strips and one partial width strip for an E size drawing, etc.

To strip mode print, relative motion is required

between print h ad 28 and sheet medium 27 in two orthogonal directions. As indicated above, by convention, these directions are parallel to the Y-axis along the width of sheet medium 27 and parallel to the X-axis along the length of medium 27. In the preferred embodiment, print head 28 is moved back and forth parallel to the Y-axis relative to medium 27, and medium 27 is moved back and forth parallel to the X-axis relative to print head 28. For clarity and ease of expression, movement of medium 27 past print head 28 in the forward direction (from bottom 40 to top 41 of medium 27) will be referred to as "downstream" or positive "X", and movement of medium 27 in the opposite direction will be referred to as "upstream" or negative "X".

Depending on the particular print head 28 used, it and sheet medium 27 may be indexed relative to each other from line to line, dwelling in each line a sufficient time to print therein, or as is typical, print head 28 and sheet medium 27 may be continuously moved relative to each other in the X-direction at a speed which permits printing as desired in each line, and then indexed in the Y-direction from strip to strip. Also, whether the print head 28 and sheet medium 27 are indexed relative to each other in the X-direction or moved continuously relative to each other in the X-direction, there may be continuous relative movement in the X-direction and in the Y-direction over lines where no part of the image is to be printed; and for groups of contiguous lines in which no part of the image is to be printed, the print head may be raised or moved away from the sheet medium to a non-printing position to permit higher speed relative movement between the print head and the sheet medium without damaging either, and to conserve thermal transfer ribbon which is not moved past the print head when the print head is raised to the non-printing position.

In the presently preferred embodiment of strip mode printing, print head 28 is positioned in the left most

strip, which in the illustrated embodiment is partial strip 38, and sheet medium 27 is m ved upstream in the negative "X" direction relativ to print head 28 to position print head 28 at the top end 40 of medium 27. Medium 27 is then moved downstream in the positive "X direction until all parts of image 26 in strip 38 are printed and print head 28 reaches the bottom end 41 of medium 27, thereby having printed the part of the image shown in Fig. 3A. Then medium 27 is moved in the upstream direction (-"X") to reposition print head 28 at the top end 40 of medium 27, and print head 28 is indexed to position it in the adjacent full width strip 34. Indexing the print head and moving the sheet medium may be done in any order or simultaneously. Medium 27 is then moved downstream (+"X") relative to print head 28 while printing proceeds in strip 34 as shown in Figs. 3B and 3C, until print head 28 reaches the bottom end 41 of medium 27. Then medium 27 is moved in the upstream direction (-"X") to reposition print head 28 at the top end 40 of medium 27, and print head 28 is indexed to position it in the next full width strip 35. Fig. 3D shows strip 35 being printed as described above, after which medium 27 is moved to reposition print head 28 at the top end 40 of medium 27 and print head 28 is indexed to the next full width strip 36. Strip 36 is printed, after which the print head is indexed to print in strip 37. Fig. 3E shows image 26 with strips 38 and 34-36 printed, and the last part of the image being printed in strip 37.

The particular sequence of moving the sheet medium, indexing the print head and printing described above, and the starting and stopping points of the print head in each strip before indexing the print head to another strip are not critical, and other sequences and start/stop points may be employed. For example, sheet medium 27 may be moved to position print head 28 at the bottom end 41 of sheet medium 27 rather than the top end 40 to start printing in a strip,

and medium 27 may be moved upstream (-"X") relative to the print head during printing in a strip. For plotting apparatus employing a thermal transfer ribbon, as opposed to a direct thermal system, further variations are limited. As described in more detail below, the thermal transfer ribbon system is arranged so that the transfer ribbon moves from a supply reel to a take-up spool in the same direction as the direction of movement of medium 27. Therefore, realization of other variations is dependent upon coordinating movement of the transfer ribbon with movement of medium 27 or print head 28, whichever moves during printing, so that the transfer ribbon moves in the same direction as medium 27 or print head 28.

Printing Apparatus

Figs. 1 and 4 show printing apparatus 25 for strip mode printing, but for clarity and ease of presentation do not show some of the wiring, the medium being printed, and certain components such as the medium supply roll 45, the media hanger 46 and the media cutter 47, which components are shown schematically in Fig. 17. The ribbon cassette storage and transfer system 700A is shown schematically in Figs. 1 and 17, and not at all in Fig. 4, except for the ribbon cassette currently in use. Medium 27 is drawn past print head 28 as described above in connection with Figs. 3A-3E in the X-direction by an X-axis drive system 68. Print head 28 is mounted to a print carriage 62 moved in the Y-direction by a Y-axis drive system 64 (Fig. 1).

Referring to Figs. 1 and 17, printing apparatus 25 comprises a front panel 50 which includes a display 52 and a keypad 53 shown as blocks in Fig. 1. Display 52 may be a liquid crystal device for displaying various messages associated with apparatus operation including error messages for ribbon and medium error conditions, and keypad 53 may be of the pressure type for inputting initiating commands including power-on/off, clear, reset, load ribbon, load

she t medium, index sheet medium and print head, lift print head, cut sheet medium and unload plot.

Referring to Figs. 1 and 4, printing apparatus 25 comprises a base 70 to which are mounted in fixed relation to each other a Y-axis frame 72 and an X-axis frame 74. Y-axis frame 72 supports print carriage 62 and Y-axis drive system 64, and X-axis frame 74 supports a platen 76 and X-axis drive system 68. Sheet medium 27 is fed from a roll 45 thereof (shown in Figs. 6 and 17) mounted to base 70 through a slot 82 therein past print head 28 and platen 76 to X-axis drive system 68 which feeds the sheet medium to media hanger 46 (shown schematically in Fig. 17). Media cutter 47 (shown schematically in Fig. 17) mounted to print carriage 62 is moved into engagement with sheet medium 27, and carriage 62 is moved in the Y-direction across the width of sheet medium 27 to cut sheet medium 27 to a desired length. Plotting proceeds as described above in connection with Figs. 3A-3E with the print head 28 and the sheet medium 27 moved as described above. Details of the construction and operation of printing apparatus 25 are given below and in the co-pending patent applications referenced herein. With respect to media cutter 47, it may be conventional or as described in co-pending application Serial No. 07/860,000 titled "Apparatus For Cutting Sheet Media", filed March 30, 1992, and assigned to the assignee of this application. The disclosure of application Serial No. 07/860,000 is incorporated herein by reference.

Print Head Support Assembly And Raising and Lowering of Print Head

Referring to Fig. 4, print head 28 is supported from carriage 62 by a print head support 90 which provides the print head 28 with two degrees of freedom (pitch and roll), allowing the print head to pivot about a pitch axis (parallel to the Y-axis) and about a roll axis (parallel to

the X-axis). Referring to Figs. 7 and 10, the thermal elements 30 (Fig. 10) lie in an X-Y plane formed by the pitch and roll axes. As shown in more detail in Figs. 7-12, print head support assembly 90 is a gimbal-like structure comprising a pitch axis gimbal 92 and a roll axis gimbal 94.

The roll axis gimbal 94 (Figs. 7-12) comprises a support member 96 having a bore 98 (Figs. 7 and 10) extending therethrough axially aligned with the roll or X-axis, and bores 100, 101 (Figs. 9 and 10) extending therethrough axially aligned with the pitch or Y-axis, and also axially aligned with each other and registered with bore 98. A roll axis shaft 103 is rotatably mounted in bore 98 by ball-type bearings 105, 106. One end 110 of shaft 103 projects from support member 96 and is fixed to a heat sink 114 by a clamp 112 (Fig. 11) which forms part of the heat sink 114, to which print head 28 is also attached. An inner race spacer 127 is positioned on shaft 103 between bearing 106 and a snap ring 128 fixed to shaft 103 adjacent clamp 112. The opposite end 123 of shaft 103 projects from support member 96. A coil compression spring 125 is mounted on shaft end 123 retained between an inner race spacer 130 which bears against a snap ring 129 and an inner race spacer 130 which bears against bearing 105 which in turn bears on support member 96. Spring 125 acts against outer snap ring 129 and bearing 105 via respective inner race spacers 130. As a result, shaft 103 tends to travel up with respect to the view of Fig. 10, taking up all slack and bearing play until snap ring 128 adjacent clamp 112 bears solidly on bearing 106 via inner race spacer 127. A bolt 135 passing through arm 114 and threaded to arm 115 of clamp 112, when tightened, draws arms 113, 114 together about shaft end 110 to fix shaft 103 to heat sink 115, and thereby to print head 28.

Fixed in respective bores 100, 101 (Figs. 9 and 10) of support member 96 and projecting from opposed sides thereof

are respective shafts 140, 141. The pitch axis gimbal 92 comprises a generally U-shaped support member 144 fixed to carriage lower platform 146 (Figs. 1 and 7) by a bracket 147 (Figs. 9 and 10) attached to the underside of platform 146. Shafts 140, 141 are rotatably mounted in holes in opposed sides of support member 144 by ball-type bearings 158 (Fig. 10) to pivot about the axis of the shafts which is parallel to the Y-axis. One end 160 of shaft 140 projects from support member 144. A coil compression spring 156 mounted on shaft end 160 bears against a snap ring 129 via an inner race spacer 130 and against bearing 158 in support member 144 via an inner race spacer 130. Coil spring 156 resiliently axially positions shaft 140 relative to support member 144 while permitting support member 144 to pivot about the pitch axis (Y-axis).

Mounted on respective shafts 140, 141 between respective sides of support member 144 and opposed sides of support member 96 are respective coil torsion springs 160. One end of each of the torsion springs 160 is engaged by spaced pins 162 (Figs. 9 and 10) projecting from a respective side of support member 144, and the opposite end of each of the torsion springs 160 is engaged by a pin 164 projecting from a respective side of support member 96. Torsion springs 160 and pins 162, 164 urge support member 96 to rotate counterclockwise in Fig. 9 to urge the heating element array 29 against thermal transfer ribbon 172 (Figs. 5 and 7), thereby using thermal transfer ribbon 172 against sheet medium 27 and medium 27 against platen 76 in the lowered printing position of the print head shown in Figs 5 and 7. As mentioned above, print head support 90 provides print head 28 with two degrees of freedom and prevents cross-coupling between pitch and roll axis movements.

Referring to Figs. 11 and 12, print head 28 may be moved from the printing position of Fig. 11 to the non-printing position of Fig. 12 against the torsion of springs

160 by a head lifting mechanism 190. A channel 192 is formed in the end of heat sink 114 opposite the end of the heat sink to which support member 96 is connected. Two cam lobes 196 fixed to a cam shaft 198 are sized to fit and be rotatable within channel 192 to (a) be adjacent but not engaging the lower channel flange 200 of channel 192 in the lowered, printing position of print head 28 shown in Fig. 11, and (b) engage the upper channel flange 201 of channel 192 in the raised, non-printing position of print head 28 shown Fig. 12. Cam lobes 196 are mounted to cam shaft 198 so that upon rotation of cam shaft 198, the cam lobes are rotated about shaft 198 as shown in Figs. 11 and 12.

To raise print head 28 from the printing position of Fig. 11, cam shaft 198 is rotated in the positive "Y" direction (clockwise in Fig. 11) to rotate the cam lobes 196 clockwise to engage the curved camming surface 204 of cam lobes 196 with the upper channel flange 201. Continued rotation of cam lobes 196 gradually cams the print head to pivot in the positive "Y" direction against the force of torsion springs 160 until cam shaft 196 has been rotated over the angle "a" clockwise and the print head 28 reaches the raised, non-printing position shown in Fig. 12.

To lower print head 28 from the raised, non-printing position of Fig. 12 to the lowered, printing position of Fig. 11, cam shaft 196 is rotated in the negative "Y" direction (counterclockwise in Fig. 12), which allows torsion springs 160 to gradually lower print head 28 in conformance with the camming surfaces 204 of the cam lobes 196. Positive "Y" rotation of cam shaft 198 continues until the cam lobes no longer engage the channel, and stops after cam shaft 198 has rotated over the angle "a", at which time torsion springs 160 alone urge print head 28 against ribbon 172, sheet medium 27 and platen 76.

An electric motor 210 (Fig. 1) is coupled to one end of cam shaft 198 (Fig. 11) to rotate cam shaft 198. A shaft

ncoder 212 (Figs. 7-8) is arranged at the opposite end of cam shaft 198 to accurat ly determine th amount of rotation thereof. Shaft encoder 212 may be any suitable conventional encoder, e.g. of the optical or magnetic type. In the illustrated embodiment, shaft encoder 212 is of the optical type and comprises an opaque disc 214 fixed to rotate with cam shaft 196, and a sensor 216 mounted by a bracket 215 to carriage 62. Sensor 216 may be any suitable conventional optical sensor and includes a light emitting diode (not shown) and a photo detector (not shown) mounted to opposed arms 217, 218 between which disc 214 is rotated. Disc 214 extends for an angle slightly less that the angle "a". Referring to Fig. 7, with the print head 28 in the lowered, printing position, disc 214 is to one side of optical sensor 216. A positive "Y" start signal from print head controller 814 of system controller 250 (Fig. 22) causes motor 210 to rotate cam shaft 196 and disc 214 in the positive "Y" direction. Sensor 216 optically senses disc 214 passing thereby and generates a detect signal which is fed to print head controller 814 until disc 214 has been rotated for approximately the angle "a" to the other side of sensor 216 where it is no longer optically sensed, at which time sensor 216 generates a stop signal fed to print head controller 814 which in response thereto causes motor 210 to stop.

Referring to Fig. 9, to lower print head 28, a negative "Y" start signal from print head controller 814 (Fig. 22) causes motor 210 to rotate disc 214 in the negative "Y" direction. Sensor 216 optically senses disc 214 passing thereby and generates a detect signal which is fed to print head controller 814 until disc 214 has been rotated counterclockwise for approximately the angle "a" to the other side of sensor 216 where it is no longer optically sensed, at which time sensor 216 generates a stop signal. That stop signal is fed to print head controller 814 which causes motor 210 to stop. The angle "a" may be from about

150° to about 250°, and is preferably about 220°.

The positive "Y" and the negative "Y" start signals are supplied, as indicated above, by print head controller 814 to motor 210 to raise print head 28 and move it away from transfer ribbon 172 and sheet medium 27. As described herein, during printing, thermal elements in print head 28 contact the thermal transfer ribbon 72 and press the ribbon against the receptor sheet medium 27 which is supported by platen 76. By heat and some pressure for a predetermined minimum "dwell time", print head 28 activates and transfers ink carried by ribbon 172 onto the receptor sheet medium 27 while sheet medium 27 is continuously moved past print head 28. As discussed above, ribbon 172 becomes temporarily adhered to the sheet medium 27 during the dwell time as the ink is transferred thereto. Sheet medium 27 is continuously moved by X-axis drive system 68 (Fig. 1) past print head 28 at a rate slow enough to permit the print head to heat and press ribbon 172 against the sheet medium 27 for at least the minimum required dwell time. Tension is imparted to ribbon 172 by a motor 605 (Fig. 16) which drives the ribbon take-up reel 604 to cause the used ribbon adjacent the print head to be peeled of the just printed sheet medium 27 and be wound on the ribbon take-up reel 604, and such tension and the movement of sheet medium 27 cause unused ribbon to be continuously unwound from the ribbon supply reel 603 and moved into position adjacent (under) the print head. As indicated herein, the tension on ribbon 172 is controlled so as to move a continuous supply of unused ribbon adjacent print head 28 while offsetting the braking effects or drag of print head 28 on sheet medium 27. With proper tension on the transfer ribbon, this action and the ribbon tension continuously move the transfer ribbon as the sheet medium is continuously moved to place unused transfer ribbon adjacent the print head as printing proceeds. Via motor 605 (Fig. 16) in ribbon drive system 601, print head controller 814

(Fig. 22) controls and adjusts the t nsion on transfer ribb n 172 during printing. Application Serial No: (HID-186) discloses details for controlling the tension on transfer ribbon 172.

Ribbon drive system 601 (Fig. 16) also reduces the tension on transfer ribbon 172 when print head 28 is lifted to a value low enough to prevent advancement of the transfer ribbon and high enough to prevent slack in the transfer ribbon. As a result, transfer ribbon, which can be relatively expensive, particularly for color printing, is not drawn past print head 28 and wasted when the print head is raised and not printing. Raising print head 28 while not printing also allows high speed movement (e.g., 16 ips) of sheet medium 27 past print head 28 for areas of the sheet medium on which no printing is to be applied (white space skipping as described below). Since printing speeds are about 4 ips, raising the print head when not printing speeds up overall plotting by printing apparatus 25 and ensures that the ribbon and the sheet medium will not be damaged during such high speed movement of the sheet medium. Additionally, raising the print head away from the thermal transfer ribbon facilitates transfer of ribbon cassettes for color printing and when the ribbon on a cassette has been fully used.

Referring to Figs. 11 and 12, the down, printing position of print head 28 is sensed by a sensor 260 which may be of the optical or magnetic type. Sensor 260 in the illustrated embodiment is a Hall-effect sensor which comprises a magnet 262 and a Hall-effect transducer 263. Magnet 262 is mounted to a collar 264 which in turn is mounted to shaft 141 (not shown in Figs. 11 and 12) of support member 96. Rotation of shaft 141 causes magnet 262 to rotate about the axis of shaft 141. Hall-effect transducer 263 is mounted to the end 265 of a bracket 266 fixed to lower platform 146 of carriage 62 (not shown in

Figs. 11 and 12). Magnet 262 includes a slot 266 therein facing Hall-effect transducer 263. Hall-effect transducer 263 emits a signal to print head controller 814 (Fig. 22) which indicates the rotational position of print head 28. Hall-effect sensor is not a binary switch, although a binary switch-type sensor may be used which would then provide a home position signal when the sensor parts are registered to indicate that the print head is fully down and in its printing position. Hall-effect sensor is preferably an analog sensor device which provides a signal related to the relative position of the magnet 262 and transducer 263. Due to the North/South orientation of magnet 262, Hall-effect sensor provides a continuous signal which accurately represents the rotational position of print head 28. As long as print head controller 814 is receiving a given signal or signals from Hall-effect transducer 263, print head controller 814 permits thermal elements 30 to be heated. However, should print head controller 814 not receive the given signal or signals while print head 28 is in the down printing position, which indicates that the print head was kicked up or partially raised by sheet medium wadding or the like, print head controller 814 turns off the drive to thermal elements 30 to prevent over-heating thereof. This prevents the thermal elements from being damaged by excessive heat which may result when the thermal elements are heated and not in contact with a heat dissipator such as the sheet medium and the platen. The signals from Hall-effect transducer 263 are also used by print head controller 814 in the generation of the signals which control motor 210 to raise and lower print head 28.

As discussed above, to obtain a suitable optical density of the matter printed on the receptor sheet medium over the full width of relatively wide sheet medium, a uniform contact pressure of the thermal transfer ribbon is required against the sheet medium and the platen. This in

turn r quires that variations b minimized in the distanc between the array of thermal elements on the print head in its lowered, printing position and the contact surface of the platen. The remaining variations (within limits) are accommodated by the pitch axis gimbal 92 and the roll axis gimbal 94.

Referring to Figs. 6, 11 and 13, low variations in the distance between the thermal array on the underside of print head 28 and the platen 76 are obtained by utilizing stationary platen 76 according to the invention which extends over the full Y-axis printing width of printing apparatus 25, and a resilient, relatively narrow, wear-resistant, low friction contact surface 280. Any variations in the distance between the platen contact surface 280 and the thermal array are accommodated by spring loading the print head 28 (see Figs. 7-9 and the related description above) towards the platen contact surface 280 while providing it with the freedom to pivot in the pitch and roll axes, as described above, and by making the platen contact surface 280 sufficiently resilient to yield a sufficient amount under a given minimum spring pressure applied to print head 28 to cause the thermal elements to contact the thermal transfer ribbon 172 and force the thermal transfer ribbon and the receptor sheet medium 27 against the platen 76 with a uniform contact pressure over the full width of the array of thermal elements. At the same time, the contact surface 280 is wear resistant and has a low coefficient of friction.

Referring to Figs. 13 and 13A, contact surface 280 is relatively narrow, and is slightly wider than the width "W" of the thermal array 29 (Fig. 10) in print head 28. As described above, the width "W" (X-axis dimension) of array 29 of thermal elements 30 may be up to about 0.25 inch (6.4mm) wide, and in the preferred embodiment is 0.025 inch (0.64mm) wide. Correspondingly, the width (X-axis

dimension) of contact surface 280 of platen 76 is preferably twic as wid as the width "W" of thermal array 29, and in the preferred embodiment is 0.05 inch (1.28mm) wide.

With continued reference to Figs. 13 and 13A, contact surface 280 forms the outer surface of a thin contact element 290 which is supported by a resilient substrate 281 which in turn is supported by a rigid support 282. Rigid support 282 is a plate of aluminum, but may be of any suitable metal or plastic or other rigid material, connected to spaced ends or arms 405, 406 (Fig. 1) of X-axis frame 74. The plate for rigid support 282 should be sufficiently wide to provide a rigid support for contact surface 280 and also to provide structure for attaching the contact surface 280 and contact substrate 281 to the plate, and may have a width slightly wider than that of contact surface 280. A narrow plate is preferred simply to save space in the printing area of printing apparatus 25. In the presently preferred embodiment, rigid support 282 is an aluminum plate 0.5 inch (12.8mm) thick, 4 inches (10.2cm) high and 24 inches (61cm) long. Rigid support 282 tapers at its top portion 284 (Fig. 13A) to about 0.2 inch (5.08mm) in thickness and has a milled groove or slot 286 therein for receiving contact substrate 281.

Referring to Fig. 13A, a resilient yet wear resistant and low friction contact surface 280 is provided in accordance with the invention by the combination of a resilient substrate 281 received in slot 286 and a superposed wear resistant, low friction, flexible thin contact element 290 having as its outer surface contact surface 280. Contact element 290 is held over and supported by resilient substrate 281. Resilient substrate 281 comprises a natural or synthetic elastomer having a hardness in the range of from about 30 to about 60 on the A Scale durometer, with a hardness of about 45 being presently preferred. Such synthetic elastomers include Neoprene and

urethane foam (trade name Poron). Resilient substrate 281 is provided as a strip having width and height dimensions slightly larger those of slot 286. Substrate strip 281 is retained in slot 286 by a friction fit therein, although it may be bonded in slot 286 by an adhesive or ultrasonic or other appropriate bond. A friction fit is preferred so that substrate strip 281 may easily be removed and replaced as necessary. Substrate strip 281 when mounted in slot 286 presents a planar upper surface projecting from edges 291 of slot 286. Such a planar upper surface for substrate strip 281 is obtained with a strip 281 having a planar upper surface in its unstressed condition, and mounting strip 281 in slot 286 in an unstressed condition.

Still referring to Fig. 13A, the tapered top portion 284 of rigid support plate 282 is defined by angled transition surfaces 292 between the sides 294 of rigid support plate 282 and the edges 291 of slot 286. Surfaces 292 terminate at the edges 291 of slot 286. Transition surfaces 292 form an angle "b" with sides 294. Angle "b" may be in the range of from about 20° to about 60°. In the presently preferred embodiment, angle "b" is 45°. Substrate strip 281 is also tapered in the portion thereof projecting from slot 286. The tapered portion of substrate strip 281 is defined by angled transition surfaces 296 therein terminating at the top 298 of substrate strip 281. Transition surfaces 296 of substrate strip 281 also form the angle "b" with the sides 294 of support plate 282, and respectively are flush with and continuations of transition surfaces 292 of rigid support plate 282. Contact element 290 extends to the side portions 294 of support plate 282 beyond substrate strip 281 and the transition surfaces 292, and is clamped at its opposite ends 300 in grooves 302 in side portions 294 of support plate 282 by the opposed arms 304 of an elongated U-shaped clamp 305 (Fig. 12). Clamp 305 includes a base (not shown) connecting and spring loading

arms 304 towards each other. Alternatively, contact element 290 may be bonded at its ends 300 to support plate 282.

Referring to Fig. 13B, platen 76A is similar to platen 76 in that it comprises a rigid support 282A in the form of an aluminum plate to the top of which a resilient substrate 281A and a wear resistant contact element 290 are affixed, but differs in the manner in which the substrate strip and contact element are affixed. As shown in Fig. 13B, the top portion 284A of platen 76A is curved, and substrate strip 281A and contact element 290 extend over curved top portion 284A to the flat side portions 294A of rigid support plate 282A, and are supported by curved top portion 284A. Substrate strip 281A is bonded near its opposite ends 309 to support plate 282A by a suitable bond, e.g., an adhesive bond. Contact element 290 extends along the side portions 294A of support plate 282A beyond the bonded ends 309 of support strip 282A and is clamped at its opposite ends 300 in grooves 302A in side portions 294A of support plate 282A by the opposed arms 304 of elongated U-shaped clamp 305. Alternatively, contact element 290 may be bonded at its ends 300 to support plate 282A.

With continued reference to Figs. 13, 13A and 13B, contact element 290 comprises a relatively thin, wear-resistant, low friction flexible film. Film contact element 290 has a hardness in the range of from 60 to about 66 on the Durometer D Scale, and a coefficient of friction in the range of from about 0.2 to about 0.35. Film contact element 290 may be, but is not limited to being, a plastic film such as a polyolefin or a UHMW polyethylene. Film contact element 290 is of a thickness and material so that it flexes upon compression of substrate strip 281, 281A under normal pressure applied by print head 28 during printing. In the presently preferred embodiment, contact element 290 is a UHMW polyethylene film of 0.003 inch (0.076mm) thickness.

Film contact element 290 may be held in place against

substrate strip 281, 281A in any other suitabl manner, for example as described above, or by bonding film contact element 290 to strip 281, 281A, depositing film contact element 290 by thin film deposition techniques on strip 281, 281A, etc.

Print Carriage, Print Carriage Mounting And Y-Axis Drive Therefor

Referring to Figs. 1, 4 and 5, platform 146 of print carriage 62 is pivotally supported from Y-axis frame 72 for movement back and forth parallel to the y-axis by Y-axis drive system 64. Rods 310, 312 are mounted at opposed ends thereof aligned and spaced apart in the Z-direction to opposed ends or arms 313, 314 of Y-axis frame 72 and provide, in cooperation with structure attached to platform 146, for the support of platform 146 while permitting platform 146 to be moved parallel to the Y-axis by Y-axis drive system 64. In the illustrated embodiment, the Z direction is substantially vertical.

A bearing assembly 315 (Fig. 5) is attached to the rear end of platform 146 (opposite the end to which print 24 is attached). Bearing assembly 315 comprises a member 316 elongated in the Y-direction having a bore 317 through which lower rod 312 slidable passes. Block 316 is rotatable relative to lower rod 312. Fixed in opposed ends of bore 317 are bearings 319 which permit sliding movement of bearing assembly 315 there along and rotation of bearing assembly 315 about the axis of rod 312. Bearings 319 are spaced sufficiently apart in the Y-direction, and the diameters of rod 312 and bearings 319 are closely matched so that there is virtually no free play between member 316 and lower rod 312 which may otherwise allow bearing assembly 315 to skew in the Y-direction. This could cause carriage 62 to stick as its moved, which could in turn result in a jerking motion in the Y-direction. As shown, member 316 is simply a solid rectangular block having bore 317 extending

therethrough parallel to the Y-axis along a central elongated axis of the block. However, elongated members of other configuration may be employed to accomplish the functions described above, or two members spaced apart parallel to the Y-axis may be employed to mount bearings 319 thereto.

A flange or rear bracket 325 (Fig. 5) is attached to block 316 extending in the Z-direction (upwardly) toward rod 310 at a right angle to platform 146. By virtue of the attachment of block 316 to platform 146, bracket 325 is also attached to platform 146. A roller 330 (Fig. 4) is attached by a bracket 333 to flange 325 with the axis of the roller extending in the Z-direction adjacent rod 310. Roller 330 is rotatably supported from bracket 333 extending rearwardly past rod 310 so that roller 330 is located to the rear of rod 310. Since platform 146 is located substantially forwardly of bearing assembly 315 and roller 330, and since platform 146 supports substantial weight forwardly of bearing assembly 315 and roller 330, platform 146 pivots in the positive "X" direction (counterclockwise in Fig. 4) to engage roller 330 with rod 310. Except for engagement of carriage 62 with Y-axis drive 64 as described below, carriage 62 would be freely movable parallel to the Y-axis with low friction, and freely pivotable a limited amount until structure on carriage 62 and Y-axis frame 72 came into contact. Carriage 62 is thus fully supported by rods 310 and 312 and suspended biased in the positive "X" direction toward platen 76.

Referring to Figs. 1, 4, and 5, Y-axis drive system 64 comprises lead screw 350 supported extending parallel to the Y-axis and parallel to rods 310, 312 by spaced frame arms 313, 314, an electric motor 353 (Fig. 1), a coupling system 354 for rotating lead screw 350, and a lead screw nut 356 (Fig. 5) attached by a bracket 358 to carriage 62 for advancing carriage 62 in response to rotation of lead screw

350. Lead screw 350 is mounted at opposit ends thereof to arms 313, 314 of Y-axis frame 72 by bearings 358 (Fig. 1) A timing pulley 360 is fixed to one end of lead screw 350 which projects from arm 313 of Y-axis frame 72. Another timing pulley 362 (not visible in Fig. 1) is fixed to the shaft of motor 353, and a timing belt 364 (Fig. 1) couples the pulleys.

A lead screw drive system was selected for the Y-axis drive system 64 because it is possible with such a lead screw system to position print head 28 with excellent accuracy made possible by the accuracy of currently available lead screws, e.g., pitch errors of less than 0.0002 inch. However, due to the relatively long length of lead screw 350 which extends for the full Y-direction, it should not be loaded to avoid bending it. Moreover, due to its relatively long length, lead screw 350 is prone to sagging if not supported. The mounting system described above accomplishes these functions. Lead screw 350 is not loaded and essentially the entire weight of carriage 62 is supported by rods 310 and 312. Additionally, when carriage 62 is in the center region of its travel, the lead screw nut 356 supplies a supporting function for lead screw 350 to prevent it from sagging.

As discussed above, it is critical that the printed image align perfectly at the edges of the strips, i.e., no spaces and no overlapping. Accordingly, print head 28 must be accurately positioned in each strip in which it is to print. The drive ratio from motor 353 to lead screw 350 is such that an integral number of revolutions of the shaft of motor 353 (and the pulley connected thereto), an integral number of revolutions of timing belt 364 and an integral number of revolutions of lead screw 350 (and pulley 360) are required to index print head 28 from one strip to another. With such drive ratios, the shaft of motor 353, the pulley connected to motor 353, pulley 360 and lead screw 350 are in

exactly the same angular position when print head 28 is properly positioned in any given strip. As a result, inaccuracies in print head positioning that otherwise might result from hysteresis effects, back lash and tolerances in timing belt 364, pulley 360, the electric motor 353 and the pulley connected to motor 353 are removed from the drive system. The following drive ratio provides for the same angular positioning of the various drive components: the motor pulley has 20 teeth; the drive pulley 360 has 80 teeth and the timing belt 364 has 160 teeth. It takes 16 integer revolutions of motor pulley 362, two integer revolutions of timing belt 364 and four integer revolutions of drive pulley 360 to index print head 28 from one strip position to the next.

Additionally, to ensure accurate positioning of print head 28 at opposite ends of the path of travel of carriage 62a, a left end sensor 370 (Fig. 1) and a right end sensor 372 are mounted to rear frame member 373 of Y-axis frame 72 to respectively sense the left end home position of carriage 62 and the right end cassette transfer position of carriage 62. Sensors 370, 372 are conventional and may be of the optical type. When carriage 62 or a part thereon is sensed by a respective sensor, a left end or right end home signal is provided to motor controller 810 of system controller 250 (Fig. 22). Motor controller 810 causes motor 353 to rotate its shaft a predetermined number of integral revolutions (16 in the preferred embodiment for indexing from strip to strip) in response to strip positioning information and utilizes the left end home signal to ensure that print head 28 always starts from the same left end position. The carriage 62 is moved to the right end of the travel and the home signal from the right end sensor 372 is used during transfer of a cassette as described below.

Carriage 62 supports not only print head 28 but also the print head controller 814 (Fig. 22) of system controller

250 for controlling the th rmal print elements 30 of print head 28 (including the head heater (not shown) and fan 378, Fig. 12), head lift motor 210 and transfer ribbon take-up motor 605 (Fig. 16). As a result, the number of flexible cables required to interconnect movable carriage 62 with other parts of printing apparatus 25 is greatly reduced. Therefore, it is not necessary to use conventional unshielded ribbon cables which are prone to interference from noise and spurious signals, or alternatively to shield a large number of cables. In the preferred embodiment only three shielded cables interconnect carriage 62 with other parts of printing apparatus 25. Two cables are provided as input and output high speed links between print head controller 814 (Fig. 22) and the head expansion port 822 of system controller 250 and one cable is provided to carry the print line sync/power fail fault signal between print head controller 814 and the head expansion port 822. Power may be supplied to print head controller 814 by unshielded cables. To reduce stress on the cables and maintain them in a desired location in Y-axis frame 72, they are run in a conduit 380 (Fig. 1) attached to carriage 62. Conduit 380 includes a curved portion adjacent carriage 62 which directs movement of the cables to take place away from their terminations and to maintain a minimum bend radius in the portions of the cables in the curved portion of conduit 380.

Carriage 62 also supports a mounting and drive system 601 for a cassette 600 of thermal transfer ribbon 172, which is described below. A cassette storage and transfer system 700A may be mounted to Y-axis frame 72, as shown in Fig. 1 and schematically in Fig. 17, and discussed below.

X-Axis Drive System And X-Axis Media Path

X-axis drive system 68 as shown in Figs. 1, 4, 8 and 14 is of the pinch roller type in which the sheet medium 27 (not shown) is pinched between rigid drive rollers 402, 403

(Fig. 14) and resilient idler rollers 407, 408 (pinch rollers). Drive rollers 402, 403 are driven while pinch rollers 407, 408 are freely rotatable. X-axis frame 74 comprises spaced ends or arms 405, 406 mounted to base frame 70 (Fig. 1). A drive shaft 410 is fixed to the left end of left driver roller 402 and a short shaft 411 is fixed to the right end of left drive roller 402. Shaft 410 is supported by bearing 412 in frame arm 405 and shaft 411 is supported by a bearing 413 mounted in a bracket 420 attached to platen 76. Drive shaft 410 is also fixed to pulley 422 so that rotation of pulley 422 rotates left drive roller 402. Short shaft 411 is also fixed to right drive roller 403 at the left end thereof. Another short shaft 415 rotatably supported by a bearing 416 in frame arm 406 is fixed to the right end of right drive roller 403. Rotation of pulley 422 by X-axis drive motor 416 rotates both drive rollers 402 and 403 via reduction drive 418. The position of one pinch roller 407 is adjustable to accommodate sheet media of different widths.

The embodiment of printing apparatus 25 illustrated in the drawings may print on sheet media up to 24 inches (about 61 cm) in width, although in accordance with the invention, even wider sheet media may be printed upon by making the X-axis drive wider. A single drive roller would have had to span about 24 inches, and would have been prone to bending from the pressure applied by adjustable pinch roller 408 in the central part of the drive roller. Therefor, two drive rollers 402, 403 are provided coupled to a central shaft 411 in order to permit central support of shaft 41 by bracket 420. The spacing of drive rollers 402, 403 is such that in cooperation with the positioning of pinch rollers 407, 408, the Y-axis position of at least roller 408 in Fig. 14 is adjustable to accommodate different size standard width sheet media.

Referring to Figs. 1 and 14, coupling system 418 for X-

axis drive system 68 is a reduction drive which may comprise pulleys and a timing b lt or gears. Coupling system 418 shown in Fig. 14 comprises timing pulley 422 mounted to the left end of drive shaft 410, a timing pulley (not shown) mounted to the shaft of motor 416 and a timing belt 424 positively coupling pulley 422 and the pulley mounted to motor 416. Motor 416 is controlled by system controller 250 (Fig. 22) to rotate in the positive "X" direction (clockwise in Fig. 1) to advance sheet medium 27 in the positive "X" direction (downstream) past print head 28, and to rotate in the negative "X" direction (counterclockwise in Fig. 1) to retract sheet medium 27 and move it back (downstream) past print head 28.

Pinch rollers 407, 408 (Figs. 1 and 13) are each mounted freely rotatable in a respective pinch roller assembly 430, 431. Referring to Fig. 13, each pinch roller assembly 430, 431 is supported from a pinch roller support rail 433 mounted to arms 405, 406 (Fig. 1) of X-axis frame 74. Pinch roller assembly 431 is fixed to support rail 433 at an end position common to media of all sizes on which printing apparatus 25 prints, and pinch roller assembly 430 is slidably mounted to support rail 433 adjustable therealong in the Y-direction according to the width of the sheet medium being printed. If desired, pinch roller assembly 431 may also be made adjustable similar to pinch roller assembly 430.

Referring to Fig. 14, each pinch roller assembly 430, 431 allows for selectively moving a respective pinch roller 407, 408 away from a respective drive roller 402, 403 in order to freely move media in the X-direction, as when servicing or removing a sheet medium. The construction of pinch roller assembly 430 is described in connection with Fig. 13. The construction of print roller assembly 431 is essentially the same. Pinch roller assembly 430 includes a U-shaped bracket 440 defining a channel 441 which slidably

receives therein the support rail 433. A lever support member 443 is fixed to bracket 441 adjacent and downstream of (positive "X" direction from) support rail 433, for example by screws. A pinch roller support arm 445 is pivotally mounted to bracket 440 at pivot 447 spaced from lever support member 443 and support rail 433. Pinch roller 407 is mounted to one end of pinch roller support arm 445 adjacent and upstream of (in the negative "X" direction from) pivot 447. A spring 450 is connected at one end thereof to pinch roller support arm 445 spaced downstream from bracket 440 and pivot 447. The other end of spring 450 is connected to lever support member 443 spaced downstream from bracket 440. A lever 452 is pivotally mounted to lever support member 443 at pivot 454 spaced downstream from the connection of spring 450 to lever support member 443. Upstream end 456 of lever 452 contacts pinch roller support arm 445 downstream of pivot 447 and spring 450, and downstream end 457 projects from the respective assembly 430, 431 so as to be accessible to be engaged by one's finger and pivoted.

With continued reference to Fig. 13, end 456 of lever 452 is curved and contacts pinch roller support arm 445, functioning as a cam surface. Curved end 456 of lever 452 in cooperation with spring 450 and pinch roller support arm 445 also functions as a detent to hold lever 452 in the broken line position in Fig. 13. In the solid line rest position of lever 452, lever 452 does not engage pinch roller support arm 445, and spring 450 alone urges pinch roller support arm 445 to pivot clockwise to cause pinch roller 407 to resiliently engage drive roller 402, so that sheet medium 27 therebetween may be moved upon rotation of drive roller 402. To disengage pinch roller 407 from drive roller 402, lever 452 is pivoted counterclockwise until lever 452 reaches the stable detent position shown in broken lines in Fig. 13. In that detent position of lever 452,

pinch roller support arm 445 is pivoted clockwise to move pinch roller 407 (broken lin s in Fig. 13) out of engagement with drive roller 402. This allows the she t m dium to be manually moved. To engage pinch roller 407 and drive roller 402, lever 452 is moved clockwise a small amount away from the detent position, at which time spring 450 pivots pinch roller support arm 445 clockwise which in turn causes lever 452 to be pivoted further counterclockwise to the solid line rest position in Fig. 13.

As in most plotter applications, it is important to accurately position the sheet medium in the X-axis and with precise repeatability. Techniques for accomplishing such accurate positioning are known in the art. For example, drive rollers 402, 403 may be made rigid and non-yielding (e.g., of aluminum or other metal) and provided with roughened surfaces defined by small projections, and pinch rollers 407, 408 may be made resilient and yielding. The drive rollers in addition to frictionally engaging the sheet medium against the opposing pinch rollers make indentations and/or small holes in the sheet medium. The indentations and/or holes in the sheet medium consistently mate with the projections that made them in the nature of a sprocket wheel drive system while the sheet medium is advanced and retracted in the X-axis. Referring to Fig. 14, portions 460, 461 of drive rollers 402, 403 are provided with such roughened surfaces. The locations on drive rollers 402, 403 of such roughened portions 460, 461 correspond to the edge portions of standard width sheet media. Examples of such roughened surfaces are disclosed for example in U.S. Patent Nos. 4,384,298 (LaBarre et al.) and 3,761,950 (Yeiser), the disclosures of which are incorporated herein by reference.

Referring to Fig. 14, to position pinch roller 407 opposite the appropriate location on drive roller 402 or 403, pinch roller assembly 430 is movable along support rail 433. To that end, a set screw 465 (Fig. 4) and a threaded

hole in the top of bracket 440 are provided. Loosening and tightening set screw 465 permits adjustment of the X-axis position of pinch roller assembly 430.

Thermal strip mode printing with a thermal print head having the thermal print elements extending a substantial distance in the Y-direction introduces a drag on the sheet medium not present with moving drum-type platens or with most conventional serial mode thermal print heads. In conventional pen plotters, a small amount of frictional drag is generated by the pen down-force against the sheet medium and supporting platen (in the order of 30 grams), but this is generally insufficient to cause mis-registration of the media with the drive system. However, in the thermal printing apparatus 25 disclosed herein wherein the thermal elements of the thermal print head extend for a substantial Y-axis distance, e.g. up to about 4 inches (about 10 cm), the down-force applied to the thermal print head is typically 1000 grams or more in the down position in order to provide adequate contact pressure against the media and supporting platen. Such a large down-force produces a resultant frictional drag force of, typically, 525 grams, and when this is applied at one side of the media, sufficient distortion of the sheet medium may occur to cause mis-registration of the sheet medium with the X-axis drive system.

Referring to Fig. 13, in addition to the provisions described above associated with platen 76 for reducing drag on the sheet medium, the effects of such drag may be minimized by stiffening the sheet medium and reducing frictional drag on the sheet medium between print head 28 and drive rollers 402, 403. The provision of a bend of small radius in the sheet medium, parallel with the Y-axis and located between the thermal print head/platen interface and the X-axis drive system, adds stiffness to the sheet medium by increasing section depth normal to the X-axis,

thus resisting distortion. How ver, as the sheet medium is pulled under the print head where the high frictional drag force is generated, further frictional drag forc s are generated between the sheet medium and a stationary radiused guide which produces the bend in the sheet medium as the sheet medium is pulled around it, in the manner of a rope wrapped around a windlass.

As presently preferred, such stiffening of sheet medium 27 and reduction in drag is accomplished by providing guide rollers 500 (Figs. 1, 4, 13 and 15) in the sheet medium path downstream of print head 28 and upstream of drive rollers 420, 403 and by providing a bend of small radius in the sheet medium parallel with the Y-axis located between print head 28 and drive rollers 402, 403. Referring to Fig. 13, such bending is obtained at guide rollers 500 by changing the sheet medium path starting at guide rollers 500 by an angle "c" relative the platen top contact surface 282. A bend radius of about 1/4 inch has been found to be suitable. However, the particular bend radius and the particular value of angle "c" are not critical. An angle "c" of 45^0 is preferred and has been found to provide the desired stiffness. A 45° angle "c" positions the sheet medium 27 along a tangent of rollers 500 and along a tangent to the interface of drive roller 402 and pinch roller 407, as shown in Fig. 13. However, an angle "c" of from about 30° to about 60° will provide a bend in sheet medium 27 sufficient to stiffen it as described above.

By the incorporation of one or more freely rotatable guide rollers 500 at the bend, the "windlass" effect of a non-rotatable shaft is eliminated, but the increased stiffening of the sheet medium by the bend therein is retained, and is sufficient to overcome the effects of the asymmetrical frictional drag force on sheet medium registration. Referring to Fig. 13, by positioning drive rollers 402, 403 (not shown in Fig. 13) and pinch rollers

407, 408 (not shown in Fig. 13) of the X-axis drive system 68 such that sheet medium 27 is presented tangentially to guide rollers 500 and also to the print head/platen interface, distortion of the sheet medium, due to bending forces at the point of registration with the X-axis drive system, is eliminated.

Referring to Figs. 13 and 15 five guide rollers 500 each about 5 inches in length are provided to span the full Y-axis width. Each guide roller 500 has stub shafts 501 and locating shoulders 502 at both ends. Guide rollers 500 are rotatably mounted in housings 503. Bearings (slots 504 in plastic housing act as bearings) rotatably support respective stub shafts 501 in respective slots 504 of respective housings 503. Each guide housing 503 has a slot 505 therein through which suction from a vacuum chamber 507 is applied to sheet medium 27. Guide surfaces 510 and 511 are formed upstream and downstream, respectively of guide rollers 500. Guide 510 defines a first guide surface, guide rollers 500 define a second guide surface, and guide 511 defines a third guide surface. A vacuum chamber 507 is formed below guide roller housings 503 to draw sheet medium 27 against guide rollers 500 when a vacuum is created in vacuum chamber 507 by an exhaust fan 512. Drive rollers 402, 403 extend in a slot 509 in the downstream end of vacuum chamber 507 and sheet medium 27 is also drawn against drive rollers 402, 403 in slot 509 when a vacuum is created in vacuum chamber 507. Vacuum chamber 507 is closed except for slots 505 and 509 and an exhaust port (not shown) communicated with an exhaust fan 512 mounted to cover 516.

The sides of vacuum chamber 507 (Fig. 13) are formed by X-axis frame arms 405, 406. The upstream end of vacuum chamber 507 is formed by platen 76 and a cover 514 connected to platen 76. The bottom of vacuum chamber 507 is formed by another cover 516 connected to cover 514 spaced above base 70. The downstream end of vacuum chamber 507 is formed by a

continuation 520 of bottom cover 516 bent upstream towards drive rollers 402, 403, a front she t medium guide 522 connected to cover continuation 520, and drive rollers 402, 403. Third guide 511 defines the top of vacuum chamber 507 which is formed by guide roller housings 503.

In an alternative embodiment (not shown), a low friction path between print head 28 and drive rollers 402, 403 may be provided pneumatically rather than by guide rollers 500. In that embodiment, sheet medium 27 is made to ride on a cushion of air (or other gas), or on an "air bearing", between the platen and the X-axis drive rollers.

In still another embodiment, a low friction static flat or configured surface (not shown) may be provided as the low friction path between print head 28 and X-axis drive rollers 402, 403 for use with certain sheet medium. However, such a static surface may not reduce friction as much as the embodiments previously described, and therefore it may also be necessary to provide a more robust X-axis drive system.

Further details regarding media stiffening and frictional drag reduction are described in application Serial No. 07/920,115 (HID-181/182).

Referring to Fig. 17, a media hanger 46 is mounted downstream of (in the positive "X" direction from) X-axis drive system 64 (not shown in Fig. 17) for holding medium 27 during cutting thereof upon completion of printing. Media hanger 46 includes a bar 540 extending parallel to the Y-axis about which sheet medium 27 is hung or draped, and spaced link arms 542 connected at one end to bar 540 and at the opposite end to a drive system (within block 835 in Fig. 22). Referring to Fig. 22, the stacking drive system in block 835 is under control of motor controller 810 of system controller 250 and pivots link arms 542 (Fig. 17) about an axis parallel to the Y-axis and thereby moves bar 540 about the arc of a circle among a cutting position referenced by 544 in which sheet medium 27 is cut, a printing position

referenced by 545 in which printing is applied to sheet medium 27 and a print retrieval position 546 in which a finished print is held for removal from printing apparatus 25. Media hanger 84 may be conventional, and may be constructed and operated as generally described in U.S. Patent No. 4,734,716 (Silverberg et al.), the disclosure of which is incorporated herein by reference.

Transfer Ribbon Cassette And Ribbon Drive System

Referring to Figs. 4, 5 and 16, thermal transfer ribbon 172 is contained within a cassette 600 which is mounted to ribbon drive system 601 carried by print carriage 62. Referring to Fig. 16, cassette 600 includes a housing 602 within which are rotatably mounted a transfer ribbon supply reel 603 and a transfer ribbon take-up reel 604. Ribbon drive system 601 comprises a take-up reel drive motor 605 having a shaft 607 (functioning as a take-up spindle) projecting from and rotated by motor 605, a supply spindle 608, and shaft encoder discs 610 and 612 attached to take-up spindle 607 and supply spindle 608, respectively. Shaft encoder disks 610 and 612 form part of sensors 652 (described below), only one of which is shown in Fig. 1. Drive motor 605 and spindle 608 are supported by opposed walls 616, 617 of a ribbon drive housing 618 which is mounted on carriage 62. Take-up spindle 607 projects from wall 616 a substantial distance sufficient to enter cassette housing 602 and be received in take-up reel 604, and also projects from opposite wall 617 a short distance sufficient to rotate the shaft encoder disc 610 mounted on the outside of the wall 617. Similarly, supply spindle 608 projects from opposite wall 616 a substantial distance sufficient to enter cassette housing 602 and be received in supply reel 603, and also projects from wall 617 a short distance sufficient to enable rotation of the shaft encoder disc 612 mounted outside of the wall 617.

The reels 603, 604 (Fig. 16) are mounted for rotation

in cassette housing 602. A drive sprocket 625 is affixed to projecting take-up spindle 607 adjacent wall 616 to engage take-up reel 604 and thereby enable the motor 605 to rotate the take-up reel. A drive sprocket 626 is fixed to projecting supply spindle 608 adjacent wall 616 to engage supply reel 603 so that supply spindle 608 rotates with supply reel 603. Ribbon take-up reel 604 has a central recess at the end thereof toward the housing 618 for receiving the drive sprocket 625, and ribbon supply reel 603 has a central recess at the end thereof toward the housing 618 for receiving and engaging the sprocket 626. Rotation of take-up spindle 607 by motor 605 causes take-up reel 604 to rotate and wind ribbon thereon from supply reel 603 which rotates relatively freely under the braking action of a brake. The brake may be comprised, for example, of a brake rotor 647 affixed to the shaft 608 and adapted to be engaged by a suitable brake pad 648 mounted to the housing 618.

Shaft encoder discs 610 and 612 (Fig. 16) form part of sensors 652 (only one of which is shown in Fig. 1), and are mounted for rotation with take-up spindle 607 and supply spindle 608, respectively. Sensors 652 are preferably of the optical type. Each disk 610, 612 comprises an opaque disc having holes therein or markings thereon, and sensors 652 may be conventional optical sensors which include a light emitting diode (not shown) and photo detector (not shown) mounted to opposed arms between which the respective disc 610, 612 is rotated. Sensors 652 provide data to system controller 250 (Fig. 22) which determines the diameter of ribbon wound on supply reel 603 and take-up reel 604. This information is used by system controller 250 to adjust the tension on ribbon 172. Additionally, the shaft encoder information may be used by system controller 250 to track actual transfer ribbon use and for transfer ribbon replenishment. Details of the determination of ribbon diameters on the reels and determination of transfer ribbon

tension and usage are described in application Serial No. (HID-186).

Referring to Fig. 16, cassette 600 is removably or releasably mounted to ribbon drive housing 618 as follows. A cassette holder referenced generally by 650 comprises flexible, cassette retention snaps 651 which are affixed to and extend from the front 653 and rear 654 of drive housing 618 beyond wall 616 and two locating assemblies 605 (only one of which is shown). Retention snaps 651 thus are spring-loaded and act as leaf springs. The end of each retention snap 651 is structured so as to engage a lug 660 on the exterior front 663 and rear 664 of cassette housing 602 and thereby retain a cassette. Also the end of each retention snap 651 is structured to permit a retention snap of an unoccupied cassette holder to cam a retention snap of an occupied holder out of engagement with the lug on the retained cassette that the later holds, and into engagement with the retention snap of the unoccupied holder, thereby effecting an automatic and direct transfer of a cassette from one holder to the other simply by moving aligned cassette holders into and out of engagement with each other.

With continued reference to Fig. 16, the end of each retention snap 651 resembles in cross section the tip of a fish hook, and is structured as follows. On one side of the end of each retention snap 651 extends a sloping camming surface 655 which begins with a right angle detent surface 657. The other side 658 of the end of retention snap 61 opposite camming surface 655 is straight. Snap lugs 660 positioned on the exterior front 663 and rear 664 of cassette housing 602 contact and engage respective right angle detent surfaces 657 of respective retention snaps 651 to mount cassette 600 to housing 618. Two spaced locating and preloading assemblies 665 (only one of which is shown) are mounted to drive housing 618 to properly locate and seat

cassett 600 relativ to housing 618. Each locating and pr loading assembly 665 comprises a spring-loaded plunger 670 with a conical locating and preloading head 671 projecting therefrom. Cassette housing 602 includes corresponding locating holes 672 positioned to be engaged by respective the conical heads 671 of the plungers 670. Locating and preloading assemblies 665 assist in properly seating cassette 600 against drive housing 618 with transfer ribbon 172 in its proper position relative to print head 28, and also assist in transferring a cassette 600 to and from housing 618, as described below.

Referring to Figs. 4 and 19, cassette 600 includes a ribbon guide 680 pivotally connected to cassette housing 602 adjacent supply reel 603 and a ribbon guide 681 pivotally connected to cassette housing 602 adjacent take-up reel 604. Ribbon guides 680, 681 are spring loaded to the positions shown in Figs. 16 and 19, i.e., to extend parallel to the walls of cassette housing 602, and may be pivoted towards each other against the action of the spring loading when stored in order to reduce storage space requirements. Alternatively, guides 680 and 681 may be fixed to cassette housing 602 extending therefrom parallel to the walls thereof, or may be formed as part of the cassette itself.

As indicated above, printing apparatus 25 may print in monochrome or color. For color printing, a number of transfer ribbons of desired final colors are provided or an n color system is provided, e.g., a four color system comprising yellow, magenta, cyan and black, or both. In accordance with the invention, cassette transfer for color printing, or simply for loading a fresh cassette on carriage 62, is automated. Referring to Figs. 1 and 17, a number of cassettes 600 may be stored in a cassette storage and transfer apparatus 700a, 700b or 700c. An access door (not shown) is provided in the cabinet of printer 25 to permit easy changing of ribbon cassettes 600.

Cassette storage and transfer apparatus 700a may comprise a disk or wheel-like turret 710 to which are releasably mounted a plurality of cassettes 600. Turret 710 is located in the Y-axis path of travel of print carriage 62 at the end thereof (either the right or left end, as described below). Turret 710 is indexed by the printer system controller to position a desired cassette releasably held at a given turret location into a cassette transfer position aligned with the cassette holder mounted on carriage 62. Alternatively, a cassette storage and transfer apparatus 700b (Fig. 17) may comprise a number of cassettes 600 mounted to cassette holders on an endless belt 720 located at the end of the Y-axis travel of print carriage 62 which is indexed by the printer controller to position a desired cassette releasably held by belt 720 in the cassette transfer position. Or a cassette storage and transfer apparatus 700c may comprise a rack (not shown) carrying a number of cassettes 600. The rack may be provided with a number of cassette holders which are individually pivotally mounted to Y-axis frame 72 to pivot about an axis parallel to the Y-axis towards ribbon drive system 601, or individually translationally mounted, or the entire rack may pivot or translate. In the pivoting embodiment, print carriage 62 is positioned by the printer controller adjacent the desired cassette holder in the rack, and that cassette holder or the entire rack is pivoted under control of the printer controller to effect a cassette transfer. In the translational embodiment, the entire rack may be moved to a cassette loading position, and the individual cassette to be loaded may be translated from the rack onto the print carriage, or separate means may remove a cassette from a stationary rack and deposit it on the print carriage. Other cassette storage and transfer apparatus will be evident to those skilled in the art from the state of the art and the disclosure herein. Automated loading and unloading of a

cassette 600 from carriage 62 is described below in connection with cassett transfer apparatus 700a.

Turret 710 for cassette storage and transfer apparatus 700a as shown in Figs. 1, 8 and 18-20 is in the form of a solid disc. However, other configurations are suitable as long as the turret may carry a plurality of cassettes and be indexed. For example, turret 710 make be provided in the shape of a ring or star wheel, as described in application Serial No. (HID-185). In the embodiment of Fig. 18, turret 710 has four cassette locations, each being defined by a cassette holder 650a, which permits mounting four cassettes, for example to be used in a four color system.

As shown in Figs. 18-20, turret 710 is rotatably mounted to a turret frame 711 by a bearing 712, and turret frame 711 is in turn mounted to base 70 (Fig. 1) at the right end of printer 25. Each cassette 600 is removably mounted to turret 710 by a cassette holder 650a which is similar to cassette holder 650 shown in Fig. 16. Each cassette holder 650a includes a base plate 714 which is not required by holder 650. Also, two spring-loaded guide pin assemblies 665a assist in locating, seating and transferring a cassette instead of the locating and preloading assemblies 665 attached to the cassette drive housing 618. Referring to Fig. 18, each cassette holder 650a comprises a pair of flexible cassette retention snaps 651a extending from side 713 of turret 710. The retention snaps 651a are essentially fastened to opposed ends of a base plate 714 which is fastened to side 713 of turret 710. Alternatively, the retention snaps 651a and base plate 714 may be made one-piece. Retention snaps 651a are the same as described above for ribbon drive housing 618, and the cassettes 600 are retained by engagement of respective snap lugs 660 on a respective cassette by respective retention snaps 651a on turret 710 in the same manner as described above with respect to ribbon drive housing 618.

A pair of guide pin assemblies 665a (Fig. 18) is provided for each cassette holder 650a extending from turret 710 on opposite sides of base plate 714 about mid-way between respective pairs of retention snaps 651a. Each guide pin assembly 665a comprises three pins, the outer two of which are spring-loaded. Referring to Fig. 4, each cassette 600 includes a pair of single hole receptacle posts 718 which mate with and receive the center pin of a guide pin assembly 665a on turret 710. The two outer spring loaded pins bear against the face of the cassette and spring load it to the respective cassette holder.

Referring to Figs. 21A and 21B, a cassette 600 is automatically transferred from between a pair of retention snaps 651a on turret 710 into the pair of retention snaps 651 on ribbon drive housing 618 on carriage 62 as follows. As shown in Fig. 1, turret 710 is mounted to base 70 at the right side end of the Y-axis travel of carriage 62 such that retention snaps 651 on ribbon drive housing 618 and retention snaps 651a on turret 710 face each other. Pairs of retention snaps 651a on turret 710 extend in a circle such that whenever turret 710 is indexed, a different pair of retention snaps 651a on turret 710 will be exactly aligned with the pair of retention snaps 651a extending from ribbon drive housing 618 on carriage 62 as shown in Fig. 21A. Turret 710 is indexed (as described below) to position a desired cassette 600 in the cassette transfer position.

A cassette transfer from turret 710 to carriage 62 is effected as follows. With reference to Figs. 21A and 21B, after turret 710 has been indexed to the desired position, carriage 62 is moved parallel to the Y-axis towards turret 710 causing the ends of the retention snaps 651 of the cassette holder 650 on carriage 62 to contact the ends of the retention snaps 651 of cassette holder 650a on the turret 710 (not shown). As carriage 62 continues advancing towards turret 710, the straight side 658 of the retention

snaps 651 of the unoccupied holder 650 on carriag 62 contact the camming surface 655 of retention snaps 651 of th occupied holder 650a on turret 710 and flex the retention snaps 651 of holder 650a away from the sides of cassette 600 and out of engagement with the snap lugs 660 on the cassette. At the same time, the camming surface 655 of the retention snaps 651 of the holder 650 on carriage 62 contact the snap lugs 660 on the cassette and are cammed over the lugs with continued movement of the carriage until the snaps 651 of the holder 650 on the carriage engage the cassette lugs as shown in Fig. 21B.

Sensor 372 (Fig. 1) is positioned to indicate the right end position for carriage 62 to achieve a cassette exchange. Sensor 372 transmits a home signal to the printer controller when carriage 62 reaches the right end home position, at which time movement of carriage 62 is reversed. Thereafter, print carriage 62 is moved in the opposite direction away from turret 710, with the cassette holder 650 on the carriage engaging the cassette, and the camming surface 655 of the retention snaps 651a of the holder 650a on the turret simply sliding on the straight part 658 of the retention snaps 651 on the carriage until the respective snaps 651, 651a no longer contact each other.

Guide pin assemblies 665a (Figs. 18 and 21A and B) assist in seating a cassette 600 and in transferring a cassette 600 during a cassette transfer as follows. While at rest, guide pin assemblies 665a act to force the cassette snap lugs 660 against the right angle detent surfaces 657 of the ends of the respective retention snaps 651a. This ensures accurate, repeatable axial location of the cassette. During a cassette transfer, the outer spring-loaded pins of the guide pin assemblies 665a act to counter the force imparted by the retention snaps 651 of the approaching cassette holder 650 mounted to print carriage 62. By providing a force for the approaching retention snaps 651 on

print carriage 62 to act against, the approaching retention snaps 651 can perform their camming motions against the stationary retention snaps 651a on the turret and on the cassette snap lugs 660 on the cassette mounted to the turret. The resilient mounting of cassette 600 also guards against jamming, bending, and breakage while always ensuring that the cassette is returned to a known position, i.e., the snap lugs 660 on the cassette against the right angle detent surface 657 of the cassette holder retention snaps 651a.

Transfer of a cassette 600 on carriage 62 to turret 710 proceeds in essentially the same way, but with the unoccupied and unengaged retention snaps 651a of holder 650a on turret 710 and the occupied and engaged retention snaps 651 of holder 650 on ribbon drive housing 618 being reversed from the positions shown in Figs. 21A and 21B.

Referring to Figs. 18-20, indexing system 730 for indexing turret 710 comprises motor 732 mounted to turret frame 711, crank 734, reduction drive system 736 which couples motor 732 to crank 734, indexing arm 738 which is connected to crank 734, indexing posts 740 which extend from side 742 of turret 710 and which are engaged by hook 744 of indexing arm 738, detent posts 746 which extend from side 742 of turret 710, and a pair of detent rollers 748 rotatably mounted to detent frame 775 and spaced to receive therebetween and releasably engage a respective detent post 746 when turret 710 is in a fully indexed position, i.e., a cassette exchange position. Reduction drive system 736 comprises a timing pulley 748 fixed to the shaft of motor 732, a timing pulley 750 fixed to shaft 752 which is rotatably mounted by bearings (not shown) to turret frame 711 and a timing belt 754 positively connecting pulleys 748 and 750. Crank 734 is connected at one end 756 to shaft 752 to rotate therewith so that the opposite end 759 of crank 734 defines a circle as shaft 752 rotates. End 759 of crank 734 is connected to end 758 of indexing arm 738 by a bearing

760 so that end 758 of indexing arm 738 also rotates in a circle but at the same time is free to itself r tate about the axis of bearing 760. A spring 762 is connected to indexing arm 738 between end 758 and hook 744 thereof and to turret frame 711. Spring 762 biases indexing arm 738 towards the central axis of turret 710 so that hook 744 may engage the respective indexing posts 740.

A cassette exchange position sensor 765 (Fig. 20) and a home position sensor 766 (Fig. 19) are provided so that the printer controller may set and determine the absolute position of turret 710 at power-up and during operation. Sensors 765 and 766 are of the conventional optical type which includes a light emitting diode (not shown) and a photo detector (not shown) mounted to opposed arms. Indexing sensor 765 is mounted to turret frame 711 adjacent the periphery of pulley 750, and an opaque tab 767 is mounted to pulley 750 to rotate therewith and pass between the arms of sensor 765 as pulley 750 rotates. Sensor 765 emits a signal to the printer controller each time that tab 767 passes between the arms of sensor 765 to indicate one complete revolution of pulley 750 corresponding to indexing of turret 710 one full position. Home position sensor 766 is mounted to turret frame 711 adjacent side 742 of turret 710 and an opaque tab 767 is mounted to turret 710 so that tab 767 will pass between the arms of sensor 766 when turret 710 is rotated. When sensor 766 senses tab 767, sensor 766 emits a home position signal to the printer controller which sets and determines the absolute position of turret 710 to thereby be able to identify in cooperation with sensor 765 the locations of the cassettes loaded onto to turret 710.

Turret 710 is indexed from one position to the next as follows. Referring to Fig. 19, the printer controller activates motor 732 to rotate crank 734 clockwise one revolution which causes indexing arm 738 to move from the solid line position (#1) through positions #2, #3 and #4 and

back to position #1. In position #1, hook 744 is engaged by indexing post 740-1. In moving from position #1 to the broken line position (#2) to the left thereof, hook 744 disengages from post 740-1. Continued clockwise rotation of crank 736 moves indexing arm 78 to broken line position #3 where hook 744 engages the next indexing post 740-2. Continued clockwise rotation of crank 736 moves indexing arm 738 to broken line position #4 which due to engagement of hook 744 with indexing post 740-2 causes turret 710 to rotate clockwise so that indexing post 740-2 is at the position of the hook of the #4 position index arm, which position of indexing post 740-2 is not shown. Finally, clockwise rotation of crank 736 back to the starting solid line position (#1), causes turret 710 to be fully indexed one position so that indexing post 740-2 is at the location in which indexing post 740-1 is shown. Sensor 765 emits a signal after one revolution of pulley 750 which corresponds to one revolution of crank 736, which causes the printer controller to turn off the power to motor 732.

With continued reference to Fig. 19, detent rollers 748 are rotatably mounted in a detent roller frame 775 which is pivotally mounted at one end thereof to turret frame 711 by a pivot joint 777 and guided at the other end thereof by a spring-loaded motion limiting mechanism 779. Motion limiting mechanism 779 comprises a rod 781 slidable located at its lower end relative to turret frame 711 by a stop 782 and pivotally mounted at its upper end to detent roller frame 775 by a pivot 783. Stop 782 comprises a bracket 784 fixed to turret frame 711 and an abutment 786 fixed to the lower end of rod 781. As shown in Fig. 19, abutment 786 may be formed by a nut threaded to rod 781 and a washer held on rod 781 by the nut. A compression spring 785 is slidable mounted on rod 781 engaged at one end by detent roller frame 775 and engaged at the other end by bracket 784 of stop 782.

With continued reference to Fig. 19, detent roller

fram 775 is in the position shown in Fig. 19 with both of the detent rollers 748 engaging a detent post 746 when spring 785 is in a slightly compressed state s that detent frame 775 is urged upwardly. The force of compression spring 785 resiliently causes detent rollers 748 to engage and seat a post 746 therebetween and form a detent stop for turret 710. Clockwise rotation of turret 710 pivots detent roller frame 775 downwardly while the downstream detent roller 748 rotates, which allows detent post 746 to ride out of engagement with detent rollers 748. After detent post 746 moves away from detent rollers 748, detent roller frame 775 pivots slightly upwardly from the position shown in Fig. 10 until the motion of rod 781 is stopped by stop 782, i.e., until abutment 786 at the end of rod 781 is engaged by bracket 784. When the next detent post 746 rides over the upstream detent roller, detent roller frame 775 is pivoted away from post 746 against the force of compression spring 785. Continued clockwise rotation of turret 710 causes the next post 746 to be seated and engaged by detent rollers 748 with compression spring 785 slightly compressed as shown in Fig. 19.

Turret 710 may be expanded to accommodate more than four cassettes by increasing the diameter of turret 710, by adding additional pairs of cassette holders 650a, indexing posts 740 and detent posts 746 to turret 710, and by appropriately changing the reduction drive system 736 and coupling from motor 732 to indexing arm 738. Moreover, different drive systems for indexing turret 710 may be provided. For example, a Geneva-type drive system may be provided for bi-directionally indexing the turret, as described in application Serial No. 07/920,116 (HID-185).

SYSTEM CONTROLLER

Referring to Fig. 22, system controller 250 comprises the following major elements: central processing unit (CPU) 800, random access memory (RAM) 802, read-only memory (ROM)

804, communications controller 806, serial/parallel interface 808, motor controller 810, motor controller interface 811, high speed serial port 812, print head controller 814, front panel 50, disk interface 818, expansion ports 820, head expansion port 822, interrupt manager 824, power supply 826 and print head supply 828. CPU 800 coordinates other processing units that may be in system controller 250, for example in print head controller 814 and motor controller 810, and the overall operation of printing apparatus 25. As printing apparatus 25 is presently configured, CPU 800 is a model T425 integrated circuit available from INMOS/SGS-Thomson.

RAM 802 is a large (typically 4 - 8 megabytes) of fairly high speed low cost readable and writable semiconductor memory constructed with dynamic RAMs (DRAMs). RAM 802 is used to implement all of the FIFOs, buffers, and bit maps discussed below. CPU 800 controls reading of data from and writing of data to RAM 802. ROM 804 permanently stores the program that CPU 800 executes.

With continued reference to Fig. 22, external communications controller 806 includes interface circuits that enable printing apparatus 25 to be connected to a variety of external data sources. Typical interfaces for communications controller 806 are: RS232C (for RS232 serial port 830), EtherNet (not shown, for a local area computer network (LAN), Apple Talk (for RS422 Apple Talk port 831) and Centronics (for a parallel port). These interfaces for external devices have different data transfer rates and complexities and are known to those of skill in the art.

Internal interface 808 includes serial interface for connection to peripherals internal to or forming part of printing apparatus 25. Such interfaces are known in the art, including an RS232 serial port connected to the display 52 (Fig. 1) and keypad 53 in front panel 50. RS232 serial interfaces and ports are preferred because they are not

complex to implement, they are easy to connect and use only a single pair of conductors, as compared to parallel interfaces which require m r conductors which are harder to shield from RF emissions, as indicated above. The RS232 serial interface in internal interface 808 is a small computing element programmed to service display 52 and keypad 53, and makes connection to CPU 800 very simple and relieves CPU 800 of the burden of scanning keypad 53 for user input.

With continued reference to Fig. 22, system controller 250 also includes a high speed serial port 812 to take advantage of the built-in high speed serial link of CPU 800 and because it has very low complexity and very high data transfer rate. The high speed serial port 812 is connected to a like device in a host computer, e.g., a PC, to interface with the applications program in the host computer which provides the plot data to printing apparatus 25. System controller 250 then converts this plot data, which is conventional data as supplied to conventional plotters, to strip mode data which print head controller 814 supplies to print head 28. A high speed link is also provided between print head controller 814 and CPU 800.

Still referring to Fig. 22, motor controller 810 controls X-axis drive motor 416, Y-axis drive motor 353 and cassette turret motor 732, and receives information from the encoders and sensors associated with those motors. Motor controller 810 also controls the motors (referenced by 835 and not otherwise shown in the drawings) for media cutter 47 (Fig. 17) and media stacker 46. Motor controller 810 is microprocessor-based and programmed to perform the functions described herein, and thereby relieves the burden on CPU 800 to control those functions. CPU 800 simply sends commands to motor controller 810 to carry out specified control functions, which motor controller 810 then causes to be carried out. Motor controller 810 also issues a Print line

Sync signal to print head controller 814 (via head expansion port 822) to print a line of data. The Printline Sync signal, which is derived from the X-axis encoder (not shown and preferably of the high resolution incremental type) allows lines of data to be accurately printed on the media regardless of small variations in speed of the media. Motor controller interface 811 allows CPU 800 and motor controller 810 to communicate with each other. Head expansion port 822 implements communications between CPU 800 and print head controller 814. As mentioned, print head controller 814 is on carriage 62 and only three lines (lines 823 825a and 825b discussed below) run from the moving carriage 62 to the remaining part of system controller 250 not mounted on carriage 62.

Head expansion port 822 receives the print line sync signal from motor controller 810 and the power fail warning signal from power supply 28, and supplies those signals on line 823 to print head controller 814. The print line sync signal is a short duration pulse, whereas the power fail signal holds line 823 at a given level (low) to inform print head controller 814 of a power fail situation. Print head controller 814 issues a head fault signal on line 823 to head expansion port 822, and this signal is supplied to CPU 800 via interrupt manager 824. Commands, control signals and data between CPU 800 and print head controller 814 flow on a number of lines between CPU 800 and head expansion port 822, which in turn carries these signals to and from print head controller 814 on input and an output high speed serial port lines 825a, 825b.

Print-head controller 814 is responsible for the operation of all elements attached to carriage 62 including: thermal elements 30 (Fig. 10) in print head 28 and the associated logic; a heater (referenced by 838 in Fig. 22 and not otherwise shown in the drawings) for heat sink 115 (Fig. 11) and the associated sensor (not shown in the drawings);

h at sink fan 378 (Fig. 11); the ribbon take-up reel drive m tor 605 (Fig. 16) and associated encoders 610 and 612; and the head lift motor 210 (Fig. 210) and associated encoder 212 (Fig. 7). The logic associated with print head 28 is responsible for ensuring that print head controller 814 does not become damaged due to thermal accumulation and for heating thermal element 30 to the proper temperature. In most thermal printers logic and associated processing is provided for thermal history, hysteresis control, or dot energy control. Such thermal control is disclosed, for example, in the following U.S. patents: 4,590,488; 4,574,293; 4,814,787; 4,636,810; 4,870,428; 4,873,536; 4,887,092; 4,937,590 and 4,928,117.

Referring to Fig. 22, heater 838, the heat sink temperature sensor (not shown) and fan 378 are used to maintain a constant heat sink temperature above ambient temperature so that variations in the ambient temperature do not cause changes in print quality. Ribbon take-up reel drive motor 605 (Fig. 16) and encoders 610 and 612 provide the correct ribbon tension during printing and allow print-head controller 814 to compute the remaining ribbon supply. Head lift motor 210 and its associated encoder 212 raise and lower print head 28 during printing operations.

Still referring to Fig. 22, disk interface 818 allows, as an option, the user to attach hard disk drives to printing apparatus 25 to store fonts, forms, programs, plots or other data frequently used by the plotting apparatus during operation. Plot data coming from the user's host computer can also be stored on a hard disk, providing a large amount of storage for plots to be plotted at a later time.

Expansion ports 820 in the standard configuration allow one port to be used as a high speed serial port or as an expansion. An expansion port enables the user to add functions to printing apparatus 25 such as EtherNet or SCSI,

or to augment the computing power of CPU 800 for more complex plot languages, such as PostScript. Expansion ports 820 allow easy connection to external devices with a minimum of wires, while allowing high data transfer rates.

Interrupt manager 824 is a small logic block responsible for signalling CPU 800 of external synchronous events such as a data packet coming from an external computer, or an error from motor controller 810. CPU 800 services these interrupts as they occur.

Power supply 826 converts AC line power into DC power necessary for the operation of circuits in system controller 250. Print head supply 828 supplies the power required by the print head 28 for printing and provides a very accurate voltage, regardless of load (which varies with print data).

Operation of Printing Apparatus 25

Glossary of Terms Used in Description of Printer Operation

Page Description Language (PDL) is a syntactical construction allowing one to describe a drawing from a higher level. PDLs permit a user to draw complex shapes such as curves and characters by specifying their location on the page and the size. These shapes will be broken down by the PDL into simpler shapes (see Drawing List). The syntax of a PDL is standardized and widely published, allowing a software vendor to generate PDL data with a high degree of confidence that it will be printed correctly. Examples of PDLs are: DM/PL, HP/GL and PostScript.

Drawing List (DL) is a collection of graphical elements such as vectors, arcs, and polygons. The data is encoded in such a way as to require as little storage as possible. A DL is generally constructed by converting a drawing described by a PDL. For example, a circle might be broke into short line segments, and characters might be broken down into small filled polygons.

In this implementation, data in the DL is sorted by strip number, or Y-axis position. This relieves CPU 800

from examining the entire DL when rasterizing a particular strip. The DL is maintained as a linked list, growing in size as more data is placed into it.

Patch - A printed area in a strip where no white space skipping is done. Can be as small as 1 line or as large as an entire strip.

FIFO (First In, First Out) is a storage buffer implemented in hardware or software. Data is read from a FIFO in the same order it was written into the FIFO. A FIFO is always situated between a reader and writer. The writer can only write into the FIFO, and the reader can only read from the FIFO. A means of interrogating the empty/full status of the FIFO is provided because a FIFO has a fixed arbitrary size which is generally not known to a reader or writer, and according to system protocol, it is illegal to write into a full FIFO and to read from an empty FIFO.

White space skipping is the process of skipping large areas where there is no printed data, and over which it is advantageous to lift the print head and move the media quickly to the start of next printed area.

A strip is a data structure that has:

1) A bit map - dot patterns representing the data to printed by the print head.

2) An (X,Y) starting position, signifying where the strip is to be printed on the page. If the strip has been scanned for white space, there may be multiple starting positions, one for each printed area within the strip. Generally, the Y position will remain constant for all printed areas within a strip.

3) A length specifier, signifying how long the printed area is. If the strip has been scanned for white space, there may be multiple length specifiers, one for each printed area within the strip.

4) A ribbon number specifying the transfer ribbon cassette to be used to print the strip.

Figs. 24-28 are flow charts which illustrate operation of printing apparatus 25. Referring to Fig. 24, the top level operating routine 900 includes the following sub-routines: power-on, initialize plotter 902; receive a plot 904; parse plot data into drawing list (DL) 906; rasterize DL into bit maps 908; prepare media 910; print strip bit maps 912; and eject media and cut and stack 914. With the exception of the power-on, initialize sub-routine 902, all of the sub-routines in the top level routine 900 are active simultaneously. In other words, the receive a plot sub-routine 904 is operating at the same time as the parse plot data into DL sub-routine 906. For example, printing apparatus 25 can be receiving new plot data, parsing an already-received plot, rasterizing already-parsed display lists, and printing an already rasterized bit map while ejecting a completed plot. Because each sub-routine differs in the amount of time necessary to complete its function, FIFO buffers as described above are provided for each subroutine. These decouple each sub-routine from the others.

Referring to Fig. 23, data flows from a host computer 916 to the input FIFO buffer 917 in sub-routine 904. The data then flows to the parser 918 in CPU 800 which parses the data into the DL and loads the DL into the DL FIFO 920, according to sub-routine 906. The data then flows to rasterizer 921 in CPU 800 where the data is converted into strip bit maps and placed in a strip FIFO 922 according to sub-routine 908. The data then flows for printing to output process 923 which prints according to sub-routine 914.

Referring to the top level routine flow charted in Fig. 24, when a user activates the plotting apparatus power switch (not shown) in front panel 50, system controller 250 becomes active and causes the following functions in sub-routine 902 to be performed.

1) Memory testing and other functional testing of

electronic and electro-mechanical components.

2) Heating print head heat sink 114 to a point approximately 10° C above the maximum ambient operating temperature specified for printing apparatus 25 to operate in.

3) Lifting print head 28, if it was down, and moving print carriage 62 until the carriage is sensed by the left end home sensor 370, which then defines in absolute terms the exact position of print carriage 62.

4) Rotating the cassette turret 710 to its home position as sensed by turret home position sensor 766 so that the plotting apparatus 25 may reference by position and thereby identify the cassettes loaded on turret 710.

5) Checking for the presence of a sheet medium. If a media roll 45 is not sensed by a sensor (not shown), printing apparatus 25 notifies the user via front panel display 52 to load media. After a media roll 45 is loaded and sensed by the sensor and a sheet therefrom is fed to X-axis rollers 402, 403, 407, 408, X-axis drive 68 advances a sheet from media roll 45 until the leading edge of the sheet is sensed by a sensor (not shown). Then X-axis drive 68 advances a length of sheet medium from media roll 45, and printing apparatus 25 is ready for operation.

Referring to Fig. 25, after initialization in sub-routine 902 (Fig. 24), plotting apparatus 25 in sub-routine 904 scans input ports 840-842 for incoming data from the user's computer to determine if data is available from the host computer (step 925). Any incoming data is read from the input port (step 926) and placed in the input FIFO if it is not full (steps 927 and 928). There is an input FIFO for each input port. Plot data are formatted according to the specification of the plot language that the plotter uses. Examples of plot languages are DM/PL, HP/GL and PostScript.

Referring to Fig. 26, after a plot is received in sub-routine 904 (Fig. 24), printing apparatus 25 converts the

plot data into the drawing list (DL) in sub-routine 906. An empty DL is created (step 930), and printing apparatus 25 then builds the DL in steps 931-934 until a "Plot End" command is detected in the plot data in step 933. Data is written into the appropriate input FIFO (step 931) and characters are read from that input FIFO (step 932). Until a Plot End command is detected in step 933, the plot data is converted into vectors in step 934 which are placed into the DL. When the Plot End command is detected in step 933, the completed DL is then placed in the DL FIFO in steps 935 and 936, and the sub-routine is ready to receive and convert another plot. The DL is retained temporarily in case the user requests a re-plot of the plot.

Referring to Fig. 27, after the DL is built in sub-routine 906 (Fig. 24), printing apparatus 25 converts the DL into printable data in rasterize drawing list sub-routine 908. The DL data is read from the DL FIFO in steps 940 and 941, the transfer ribbon is set to 0 (step 942) and the strip is set to 0 (step 943). Beginning with the first transfer ribbon to be used in the particular plot in the first strip to be printed with that ribbon, as determined in step 944, printing apparatus 25 in step 945 scans the DL and, for each strip to be printed with that ribbon, converts the DL data to a bit map of the same width as the print head 28. The converted bit map is then scanned for white space in step 946. Information pertaining to where the white space in a strip appears is added to the strip. The completed strip is then placed in the strip FIFO in steps 947 and 948. This process is repeated for all strips of a particular ribbon (the completion of which is determined in steps 949-950), and for all ribbons (the completion of which is determined in steps 951-952) until the last strip is printed with the last ribbon.

Referring to Fig. 28, after each strip bit map has been built in sub-routine 912 (Fig. 24), and the sheet medium

prepar d in step 910, the plot is printed according to subroutine 914. First, printing apparatus 25 waits f r media loading if the media is not already in place (step 960). The strip FIFO is read in steps 961 and 962, and if the strip to be printed is the first strip of the plot(as determined in step 963), printing apparatus 25 in step 964 sets tracks (indentations in the nature of tiny sprocket holes, as described above) in the sheet medium by advancing the sheet medium for the length of the plot and then returning to the starting position. This may be done several times to ensure good tracks. The tracks are necessary for good registration, as discussed above. If the strip was not the first strip, and is the last strip of the plot (step 965), the sheet medium is cut and ejected in step 966 and routine 914 is ready to print another plot. If the strip was not the first or the last, the set tracks step (964) is skipped.

Still referring to Fig. 28, if the ribbon cassette that is currently loaded is not the one that will be used to print the first strip as determined in step 967, printing apparatus 25 in step 968 returns the cassette then on print carriage 62 to turret 710, rotates turret 710 to the location containing the cassette that will be used, and loads the cassette on the turret which is now to be used onto the cassette drive. Printing apparatus 25 in step 969 then positions print carriage 62 and the sheet medium at the starting position of the strip on the sheet medium. Print head 28 in step 970 is lowered onto the sheet medium and ribbon tension is applied.

Printing apparatus 25 begins moving the sheet medium 27 and sending the bit map to the print head line-by-line in step 971. This is done until all lines have been printed as determined in step 972. After the particular bit map has been printed, the X-drive and ribbon drive motors are stopped in step 973, the tension in the transfer ribbon is

decreased as described above, and print head 28 is lifted. This process is then repeated for all strips of a plot until the last strip is determined in step 965.

After all strips have been printed using all ribbons necessary to make the plot, the last used cassette is placed back in turret 710, the sheet medium is advanced out of printing apparatus 25, and the plotted sheet is cut and stacked in the output bin. Printing apparatus 25 then pulls another length of sheet medium from the media roll 45 and is ready to print another plot.

A rasterizer makes the ends of multi pixel lines rounded (similar to lines drawn with a pen). This is not desirable for lines butting up against each other at strip edges. Also, there is the case where there is a wide line at the edge of the strip that is parallel or nearly parallel to the edge of the strip. This line's endpoints exist only in one strip, but due to the width of the line, it also overlaps into the adjacent strip. To remedy this, an overlap area is provided between strips. The actual bitmap area has 8 extra pixels on each side. When lines are split into subvectors, instead of printing up to the very edge of the strip, the edge is passed by a few pixels. Lines parallel to the edge that are in overlap zone are put into both strips. Then, when the bitmap is output to the print head, the first 8 pixels and the last 8 are not output. This simplifies the design of the rasterizer, but wastes a small amount of bitmap memory.

Since the printing apparatus 25 may print at 400 dpi, a single pixel wide line will be too small to be see well. Most lines will be 3, 5 or 7 pixels wide, which is on the same order as a pen plotter.

Also, to ensure that the edges of adjacent strips "stitch" well, the thermal energy to the thermal elements is managed based on thermal history of dots printed in the last several lines, and on a thermal model developed by analysis

of printed test patterns. Thermal management may b desirable when printing renderings as opposed to line drawings, due to the large shaded areas common to renderings. Additionally, dots on or near the edge of print head 28 may undergo extra compensation to improve "stitch" effects.

While the invention has been described and illustrated in connection with preferred embodiments, many variations and modifications as will be evident to those skilled in this art may be made without departing from the spirit and scope of the invention, and the invention as set forth in the appended claims is thus not to be limited to the precise details of construction set forth above as such variations and modification are intended to be included within the scope of the appended claims.

WHAT IS CLAIMED IS:

1. A method of moving a print head for positioning the print head in a plurality of positions parallel to a first axis, the method comprising:

coupling a drive source to the print head via a coupling means including a plurality of toothed gear or pulley elements;

configuring and coupling the toothed elements coupling the drive source and the print head so that the absolute angular position of each such toothed element is precisely the same for each position of the print head in the first axis.

2. A method of supporting a print head in a given relationship to a platen extending parallel to a first axis for printing an image on a medium supported by the platen, the method comprising:

supporting the print head for pivoting a sufficient amount about an axis normal to the first axis to accommodate small variations in said given relationship so that such variations in said given relationship do not visibly affect print quality; and

supporting the print head for pivoting a sufficient amount about the first axis to space the imaging head from the platen to permit relative movement between the print head and the platen in a non-printing position of the print head.

3. A drive system for moving a print head parallel to a first axis, comprising:

a lead screw, means rotatably supporting said lead screw parallel to the first axis, means for supporting the print head for movement parallel to the first axis along said lead screw, said supporting means supporting said print head substantially without loading said lead screw, means coupling said lead screw and the print head to move the print head parallel to the first axis upon rotation of said

lead screw, and means coupled to said lead screw for rotating said lead screw.

4. The drive system of claim 3 wherein said means for rotating said lead screw comprises a motor and means coupling said motor to said lead screw, said means coupling said motor to said lead screw and said lead screw being configured to position said motor, said means coupling said motor to said lead screw, and said lead screw in exactly the same angular positions for each position of the print head relative to the first axis.

5. The drive system of claim 4 wherein said means supporting the print head comprises a first bar extending parallel to said lead screw, a member attached to said print head having an opening therethrough corresponding in cross section to the cross section of said bar, said bar passing through said opening in a supporting relationship with said print head such that said print head may be displaced along the longitudinal axis of said first bar and be pivoted relative to the longitudinal axis of said first bar, a second bar extending parallel to said lead screw and to said first bar positioned to restrain said print head from pivoting relative to said first bar while permitting said print head to be displaced along the longitudinal axis of said second bar.

6. A wide format, stationary platen for use with a print head, comprising;

a rigid, stationary support element having a length greater than 11 inches;

a resilient substrate element supported by said rigid support element for substantially all of said length of said support element, said substrate element having generally flat sides which meet at a top of said substrate element and are exposed relative to said support element and which has a width at said top of less than about 0.05 inch; and

a thin, wear resistant, low friction, flexible contact

element adjacent said top of said substrate element supported thereon so as to cooperate with said substrate element to provide a wear resistant, low friction, flexible contact surface against which said print head and any intervening medium to be printed upon may act.

7. A wide format, stationary platen for use with a print head, comprising;

a rigid, stationary support element having a length greater than 11 inches and a curved top;

a resilient substrate element supported by said rigid support element for substantially all of said length of said support element, said substrate element being supported by and conforming to said curved top of said rigid support element; and

a thin, wear resistant, low friction, flexible contact element adjacent said top of said substrate element supported thereon and conforming to the shape thereof so as to cooperate with said substrate element to provide a wear resistant, low friction, flexible contact surface against which said print head and any intervening medium to be printed upon may act.

8. In a printing apparatus the combination of a thermal print head, a wide format, stationary platen which extends in a first direction and against which said print head acts, and means for moving said print head in said first direction relative to said platen, said platen comprising;

a rigid, stationary support element having a length greater than 11 inches;

a resilient substrate element supported by said rigid support element for substantially all of the length of said support element, said support element having a top;

a thin, wear resistant, low friction, flexible contact element adjacent said top of said substrate element supported thereon so as to cooperate with said substrate

element to provide a wear resistant, low friction, flexible c ntact surface against which said print head and any intervening medium to be printed may act.

9. The platen of claim 6 or 8 wherein said rigid support element has a top extending for substantially all of the length of said support element, said top of said rigid support element being of a width which is slightly larger than the width of said top of said substrate element, a groove in said support element top in which is received said substrate element with said top thereof exposed.

10. The platen of claim 9 wherein said rigid support element has opposed sides spaced apart by a width larger than the width of said top thereof, there being a transition region between at least one side of said rigid support element and said top thereof in which said support element tapers to said top thereof.

11. The platen of claim 9 wherein said rigid support element has opposed sides spaced apart by a width larger than the width of said top thereof, said support element top being generally centered relative to said sides and there being opposed transition regions between each side of said rigid support element and said support element top in which said support element tapers to said top thereof.

12. The platen of claim 11 wherein said opposed transition regions each have outer surfaces which each form an angle of from about 20^0 to about 60^0 with a respective side of said rigid support element.

13. The platen of claim 9 wherein said substrate element has a base wider than said top thereof and a transition region between at least one side of said substrate element and said substrate element top in which said substrate element tapers between said at least one side and said substrate element top.

14. The platen of claim 9 wherein said substrate element has a base wider than said top thereof, said

substrate element top being generally centered relative to said base, and there being opposed transition regions between each side of said substrate element and said substrate element top.

15. The platen of claim 14 wherein said opposed transition regions of said substrate element have outer surfaces which each form an angle of from about 20^0 to about 60^0 with a respective side of said substrate element.

16. The platen of claim 6 or 8 wherein said thin, flexible contact element is a film having a hardness in the range of from about 60 to about 66 on the Durometer D Scale, and a coefficient of friction in the range of from about 0.2 to about 0.35.

17. The platen of claim 16 wherein said film is selected from the group consisting of polyolefins and UHMW polyethylene.

18. The platen of claim 8 wherein said rigid support element has a curved top, said substrate element is supported by and conforms to said curved top of said support element, and said flexible contact element is supported on said resilient substrate element and conforms to the shape thereof.

19. A support for a print head movable parallel to a first axis relative to a medium to be printed upon which cooperates with a stationary platen extending parallel to the first axis, said support resiliently positioning the print head against the platen and any intervening medium to be printed upon, said print head support comprising:

a roll axis gimbal element and means for attaching the print head thereto for rotation of the print head about a roll axis normal to the first axis while resiliently urging the print head against the platen relative to the roll axis and any intervening medium to be printed upon;

a pitch axis gimbal element and means for attaching said pitch axis gimbal to said roll axis gimbal for rotation

of said pitch axis gimbal about a pitch axis parallel to the first axis.

20. In a printing apparatus the combination of a print head movable parallel to a first axis relative to a medium to be printed upon, a stationary platen extending parallel to the first axis with which the print head cooperates to print on the medium, and a support for resiliently positioning the print head against the platen and any intervening medium to be printed upon, the print head support comprising;

a roll axis gimbal element and means for attaching the print head thereto for rotation of the print head about a roll axis normal to the first axis while resiliently urging the print head against the platen relative to the roll axis and any intervening medium to be printed upon; and

a pitch axis gimbal element and means for attaching said pitch axis gimbal to said roll axis gimbal for rotation of said pitch axis gimbal about a pitch axis parallel to the first axis.

21. The apparatus of claim 20 wherein said platen comprises:

a rigid support element having a length greater than 11 inches extending parallel to the first axis;

a resilient substrate element supported by said rigid support element for substantially all of said length of said support element; and

a thin, wear resistant, low friction, flexible contact element adjacent a top of said substrate element so as to cooperate with said substrate element to provide a wear resistant, low friction, flexible contact surface against which said print head and any intervening medium to be printed upon may act.

22. In a printing apparatus the combination of a print head movable parallel to a first axis relative to a medium to be printed upon, a stationary platen extending parallel

to the first axis, a support for resiliently positioning the print head against the platen and any intervening medium to be printed upon, and means for moving and holding the print head in a non-printing position a given distance from the platen, the print head support comprising;

a roll axis gimbal element and means for attaching the print head thereto for rotation of the print head about a roll axis normal to the first axis while resiliently urging the print head against the platen relative to the roll axis and any intervening medium to be printed upon; and

a pitch axis gimbal element and means for attaching said pitch axis gimbal to said roll axis gimbal for rotation of said pitch axis gimbal about a pitch axis parallel to the first axis.

23. A support for a thermal print head movable parallel to a first axis relative to a medium to be printed upon which cooperates with a stationary platen to resiliently position the print head against the platen and any intervening medium to be printed upon, the platen extending parallel to a first axis and having a length greater than 11 inches, said print head support comprising:

a pitch axis gimbal element and means for attaching the print head thereto for rotation about a pitch axis parallel to the first axis while resiliently urging the print head against the platen relative to the pitch axis and any intervening medium to be printed upon.

24. In a printing apparatus the combination of a stationary platen extending parallel to a first axis and having a length greater than 11 inches, a thermal print head having a length less than half of the length of the platen and a support for the thermal print head which cooperates with the platen to resiliently position the print head against the platen and any intervening medium to be printed upon, said print head support comprising;

a pitch axis gimbal element and means for attaching the

print head thereto for rotation about a pitch axis parallel to the first axis while resiliently urging the print head against the platen relative to the pitch axis and any intervening medium to be printed upon.

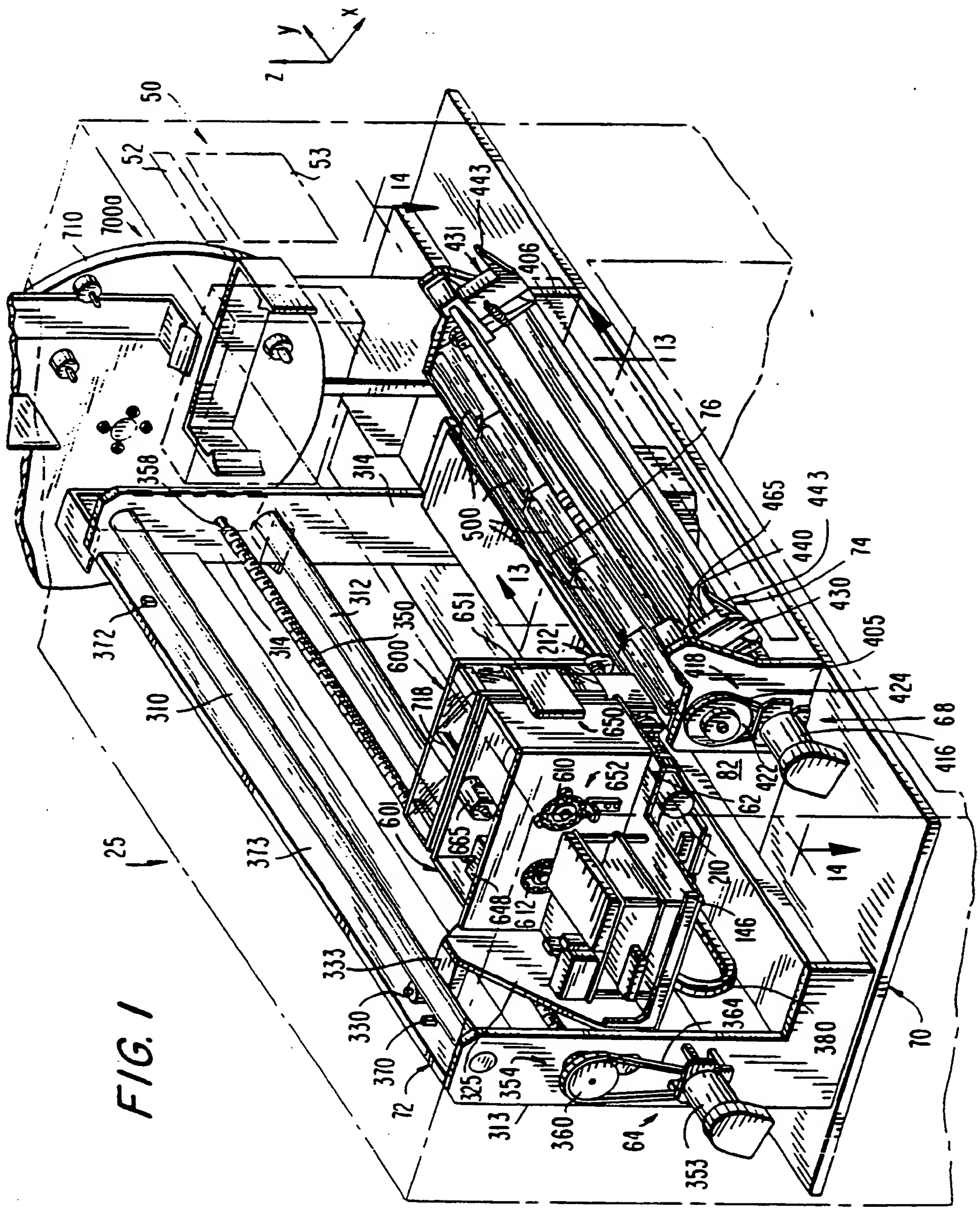

FIG. 1

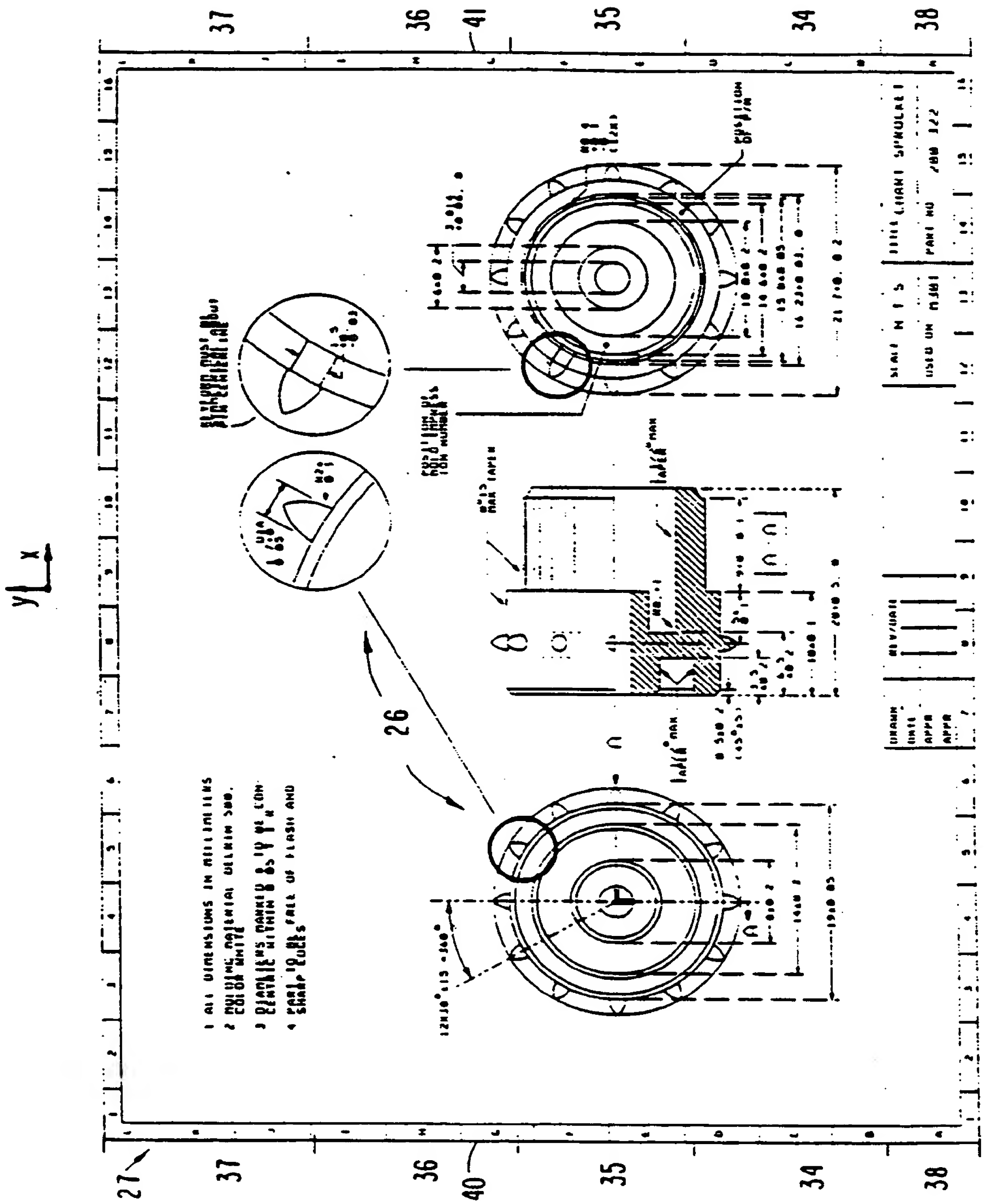

FIG. 2

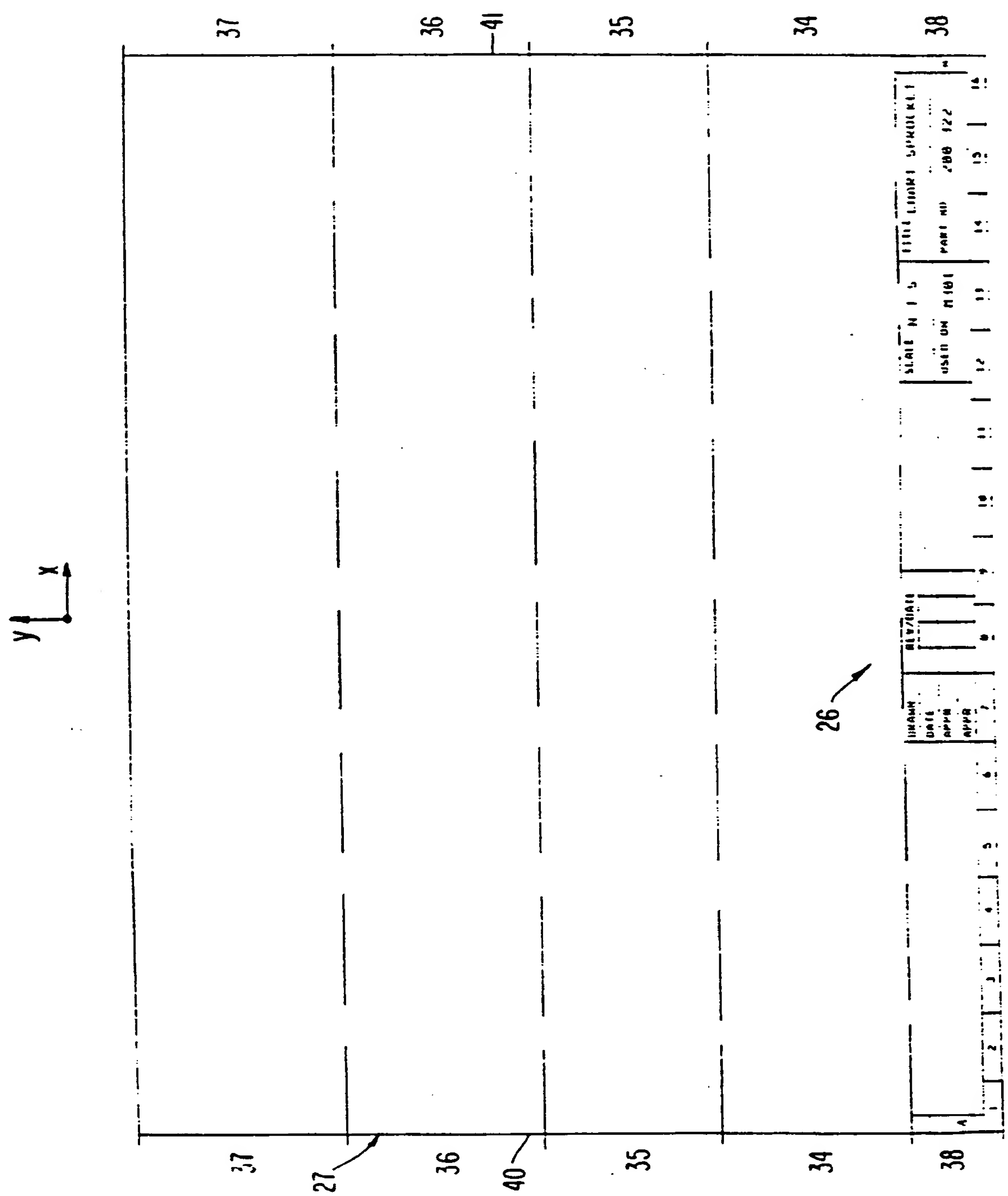

FIG. 3A

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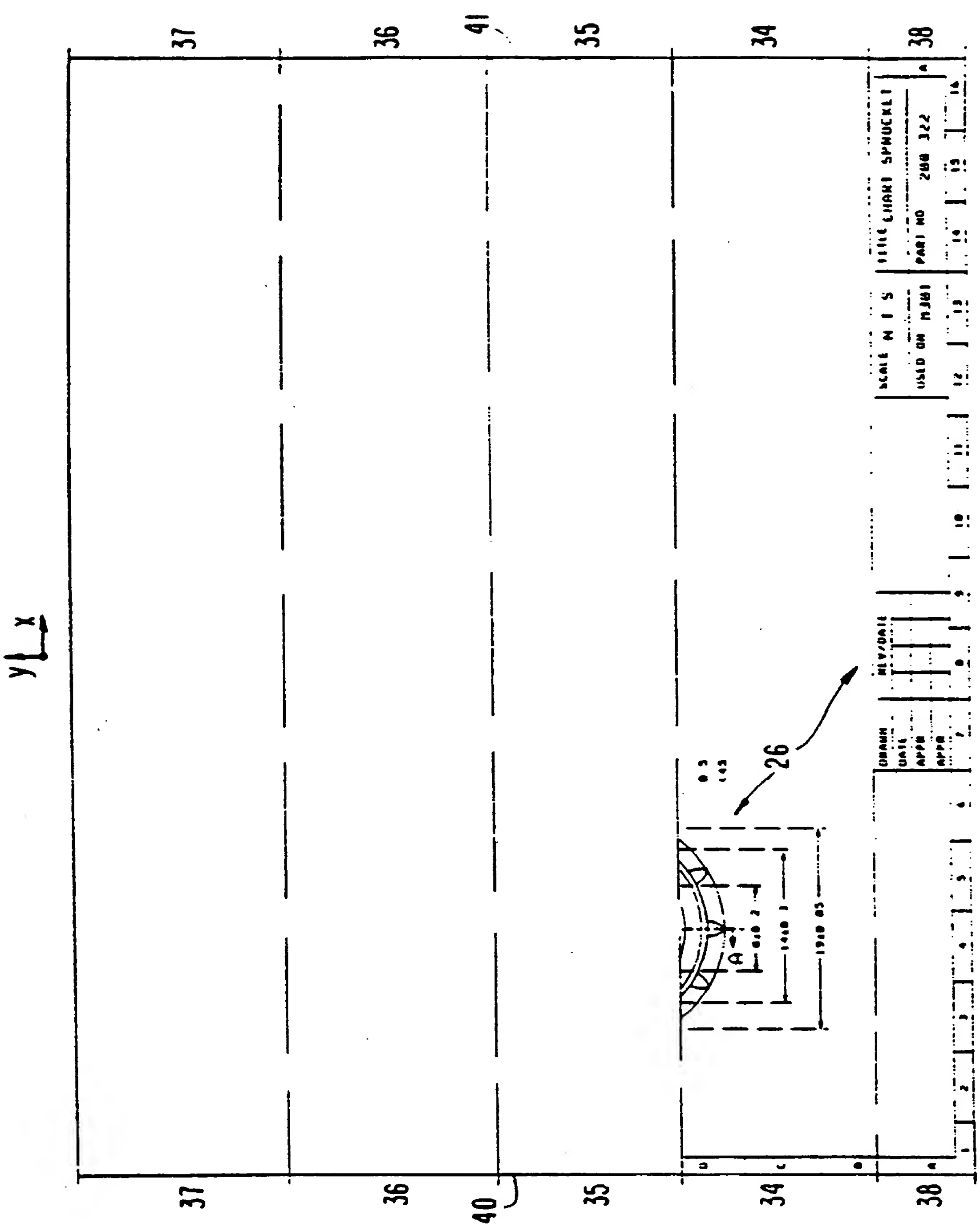

FIG. 3B

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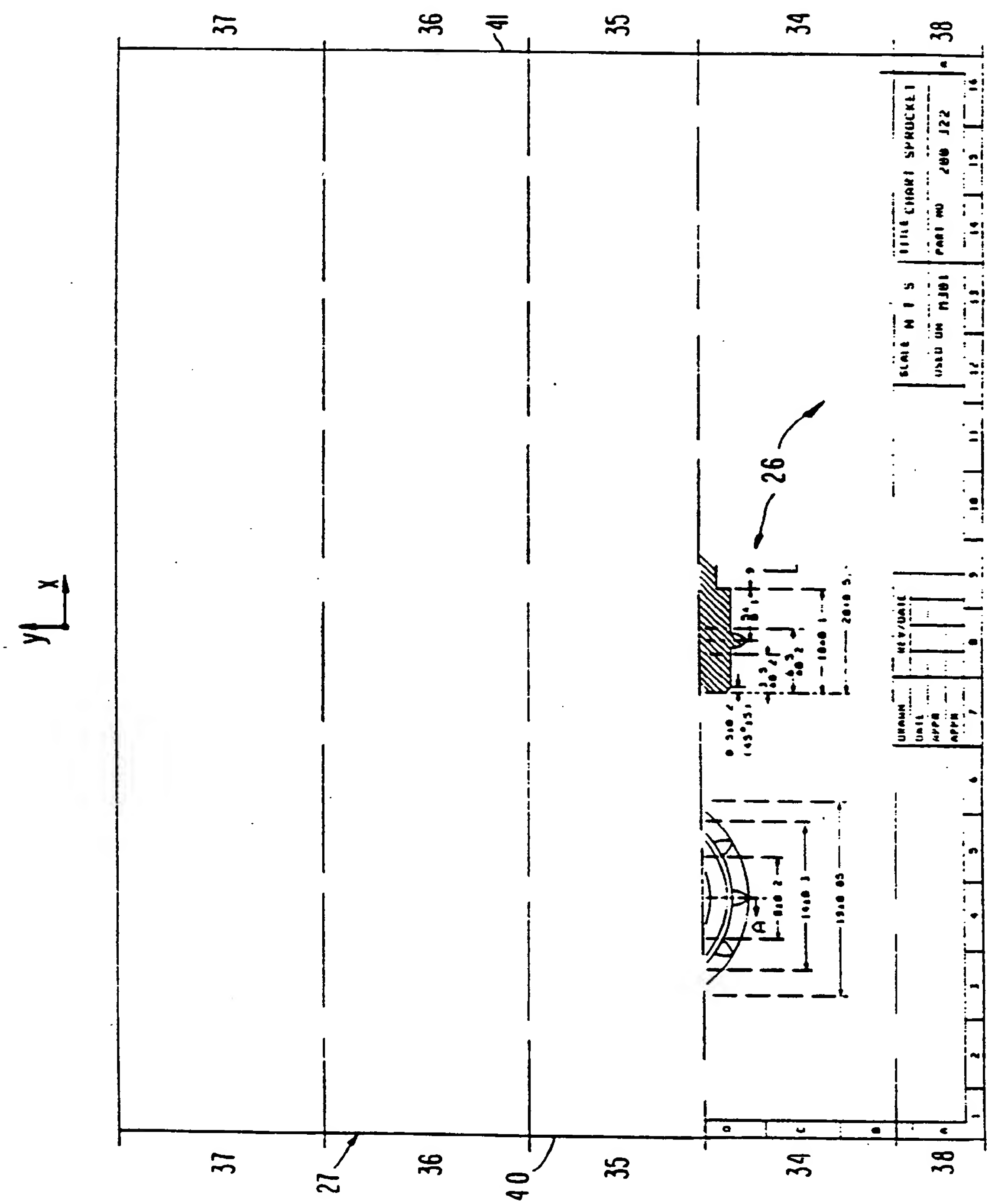


FIG. 3C

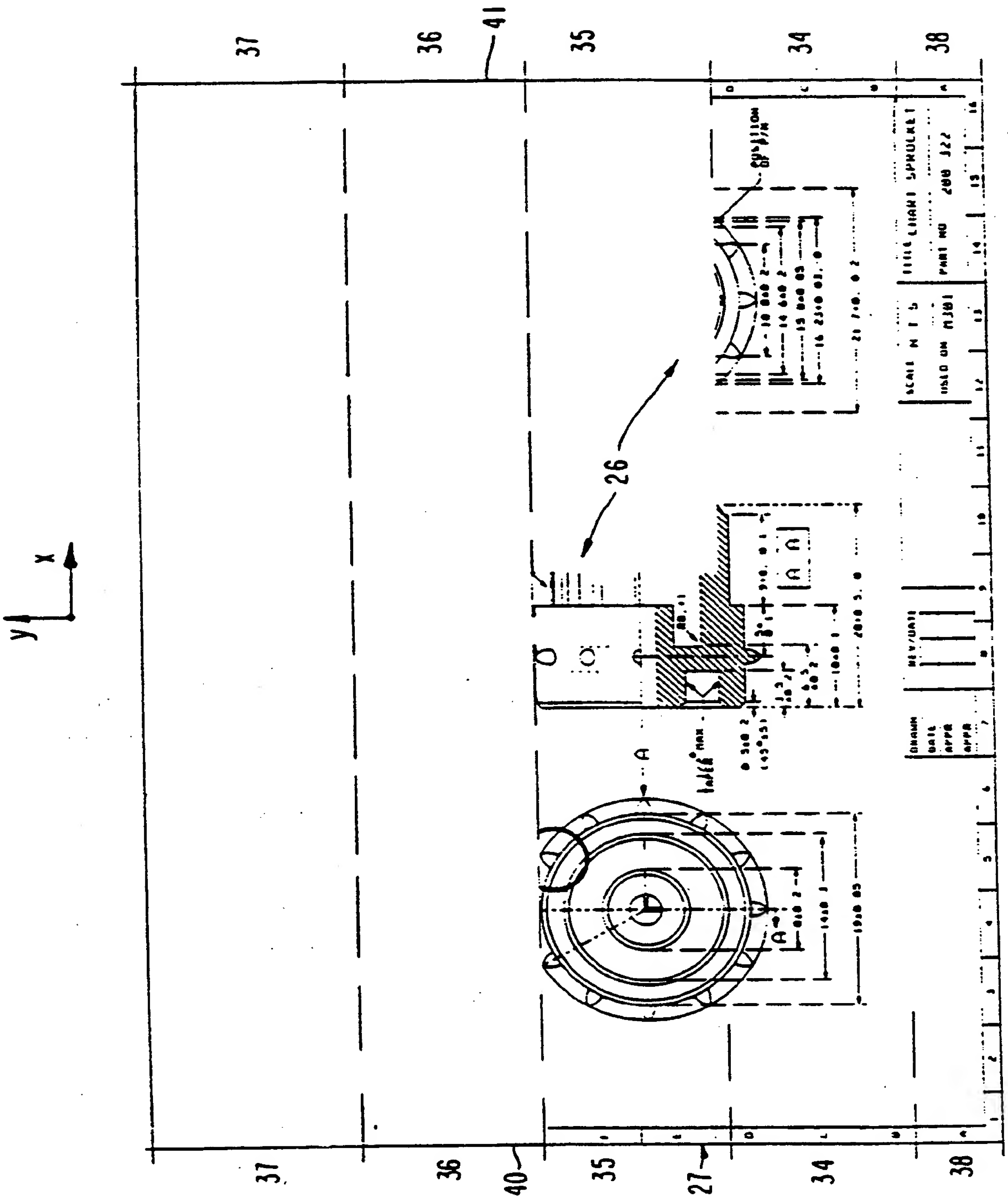


FIG. 3D

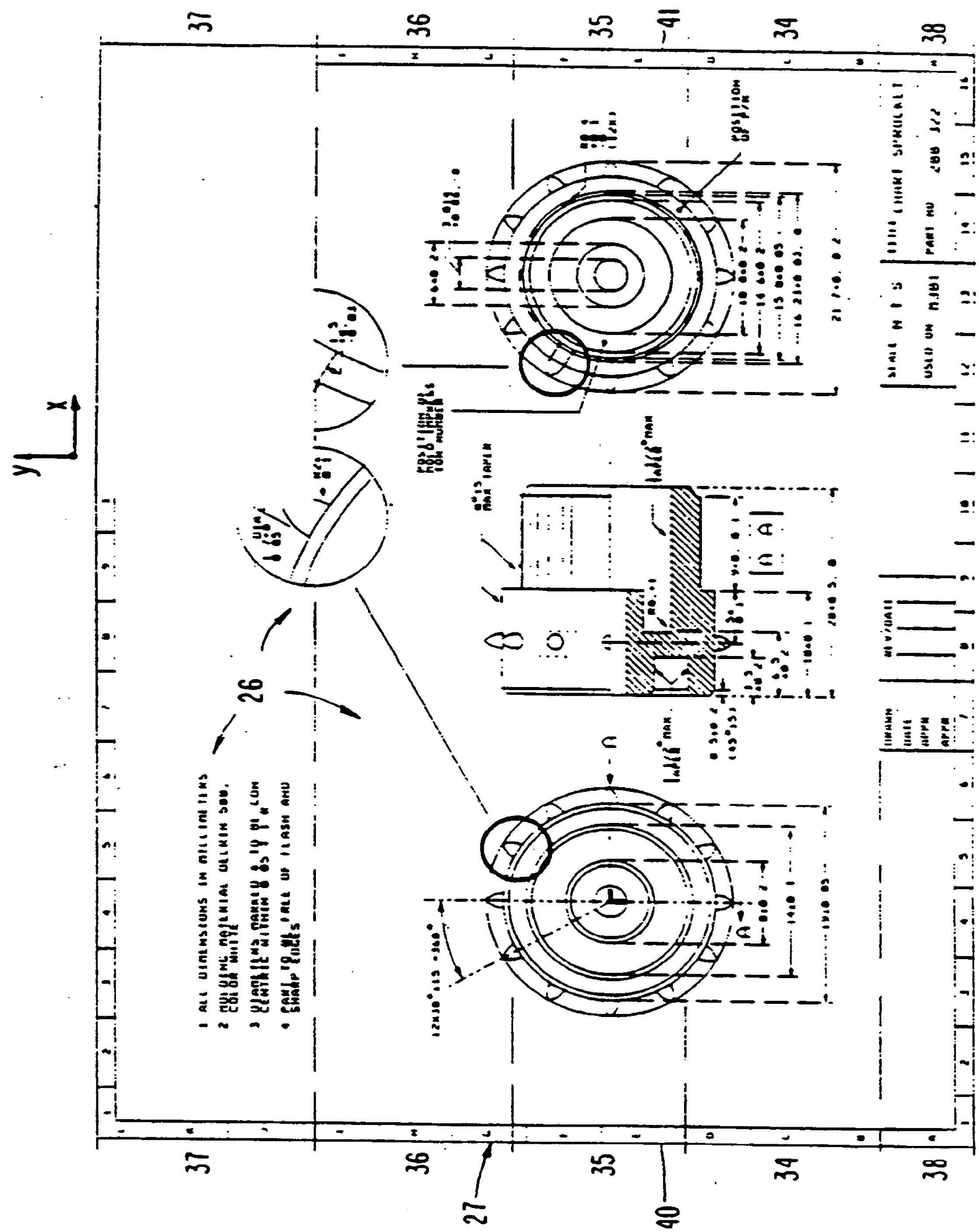
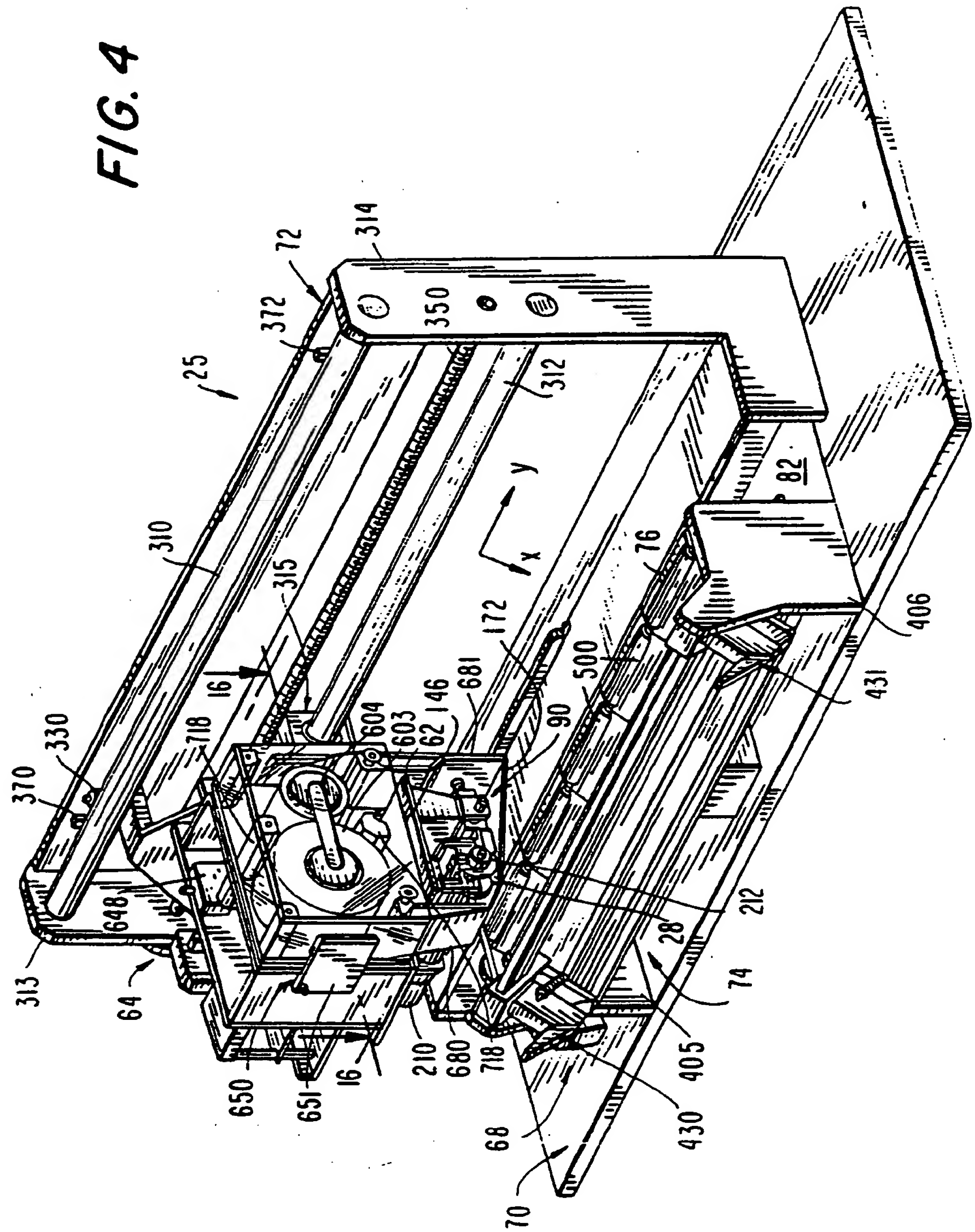


FIG. 3E

FIG. 4



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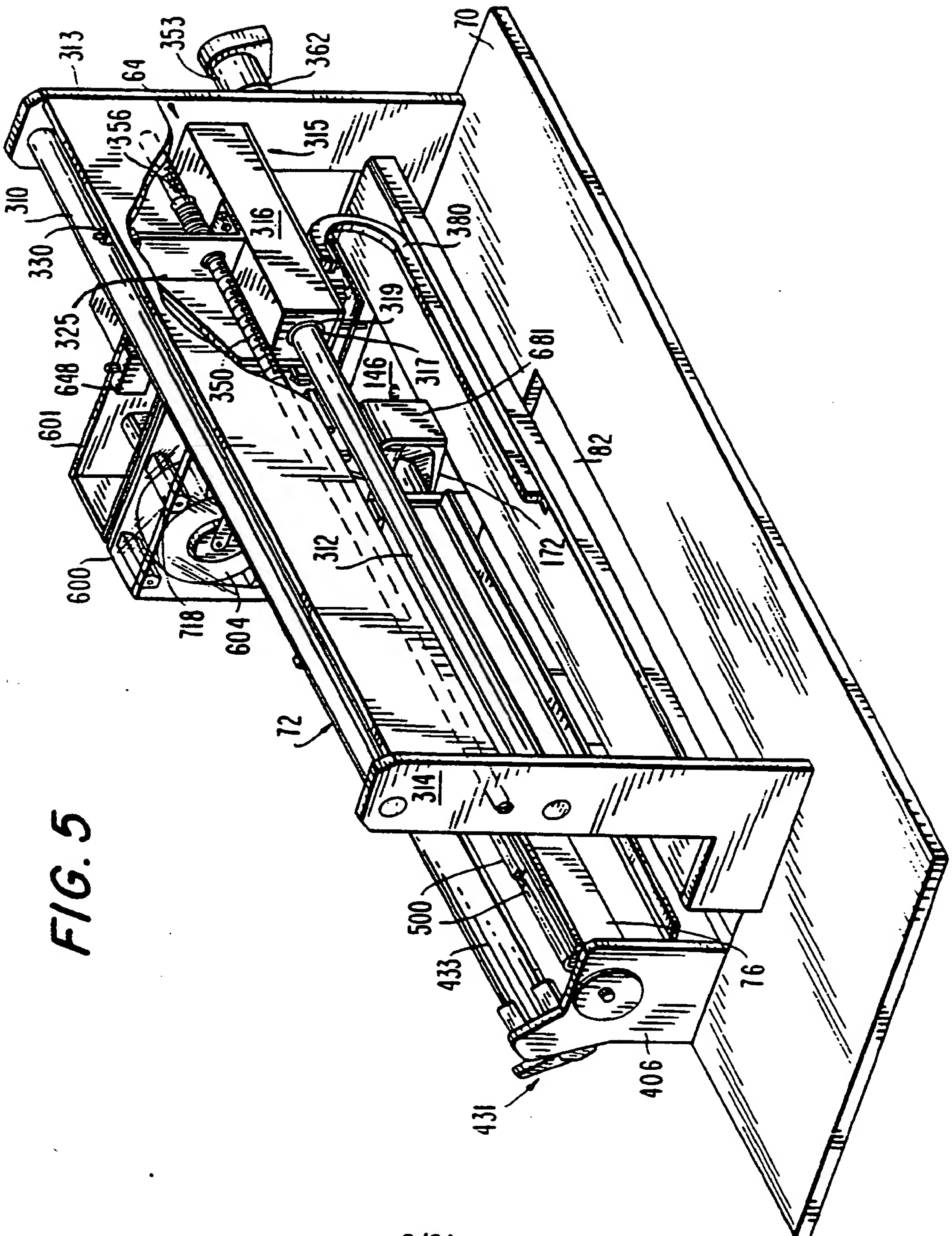
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362
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356
315
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648
350
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172
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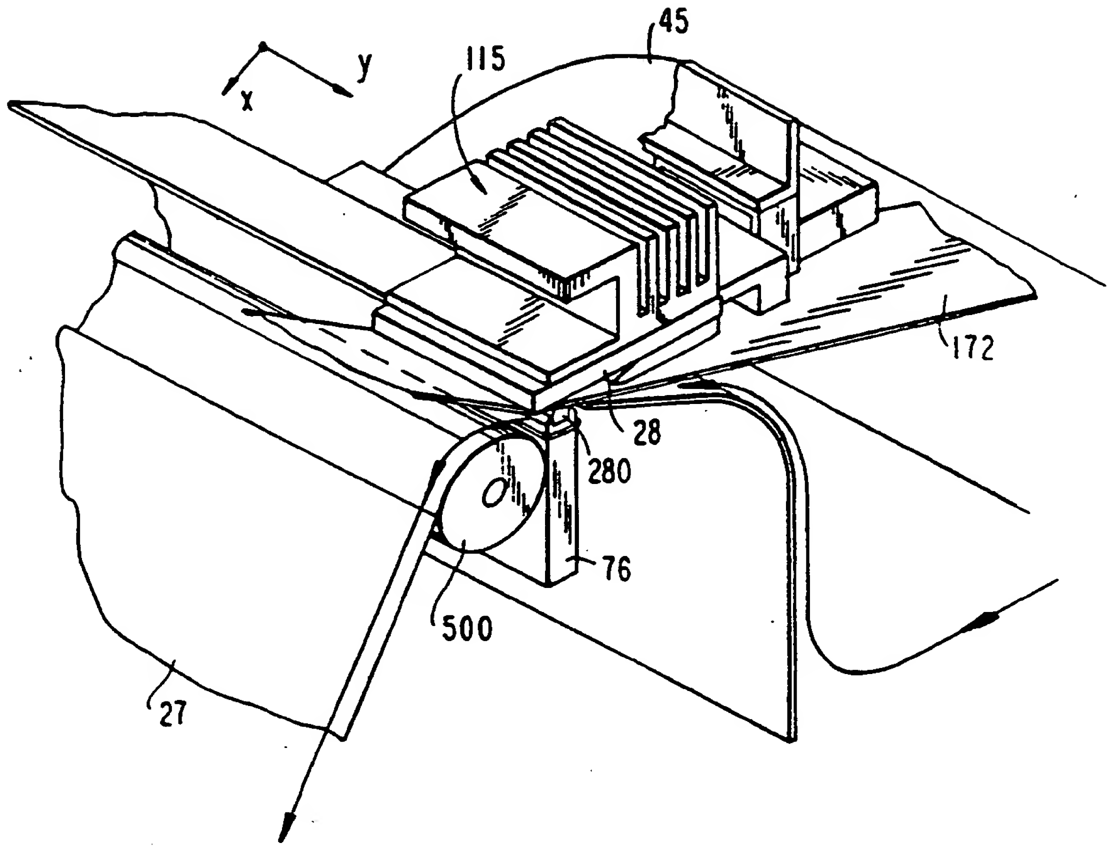
718
604
72
314
500
433
76
406
431

FIG. 5

FIG. 6



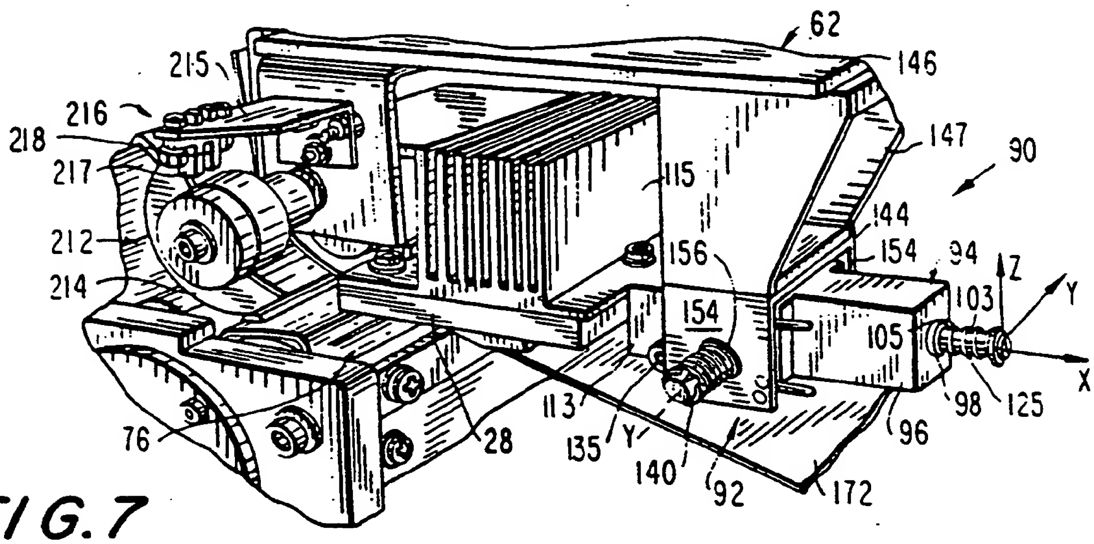


FIG.7

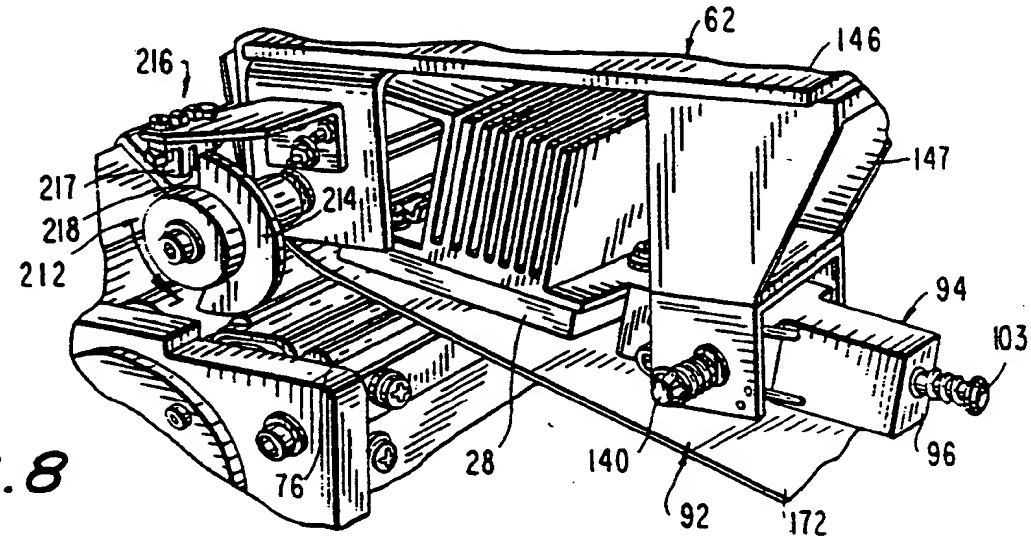


FIG.8

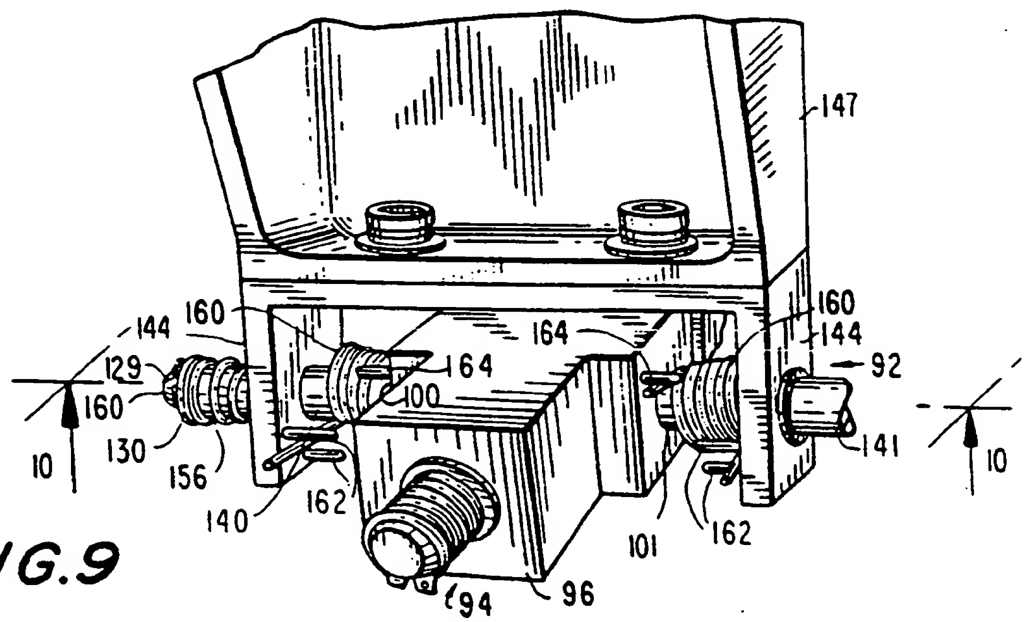


FIG.9

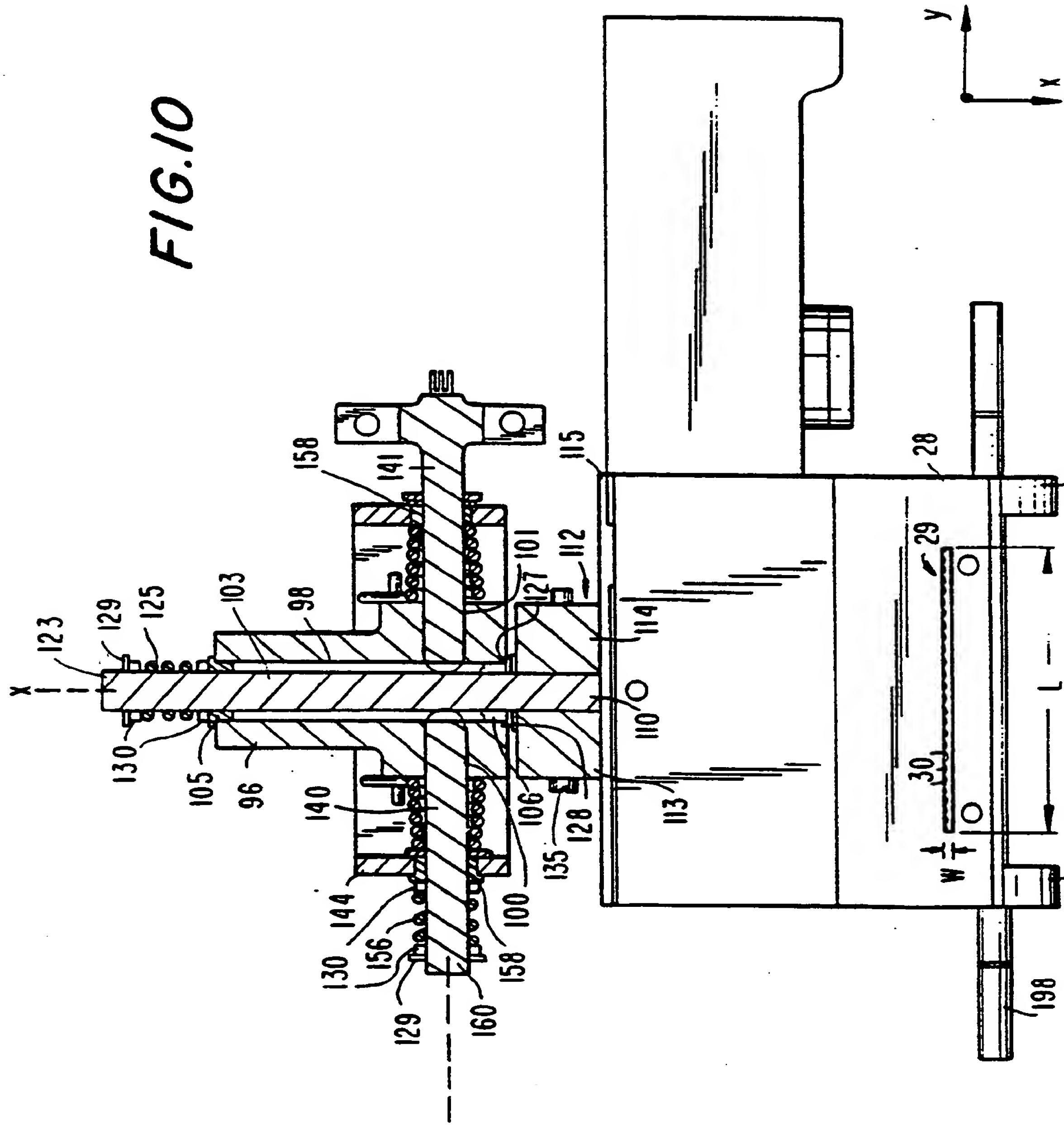
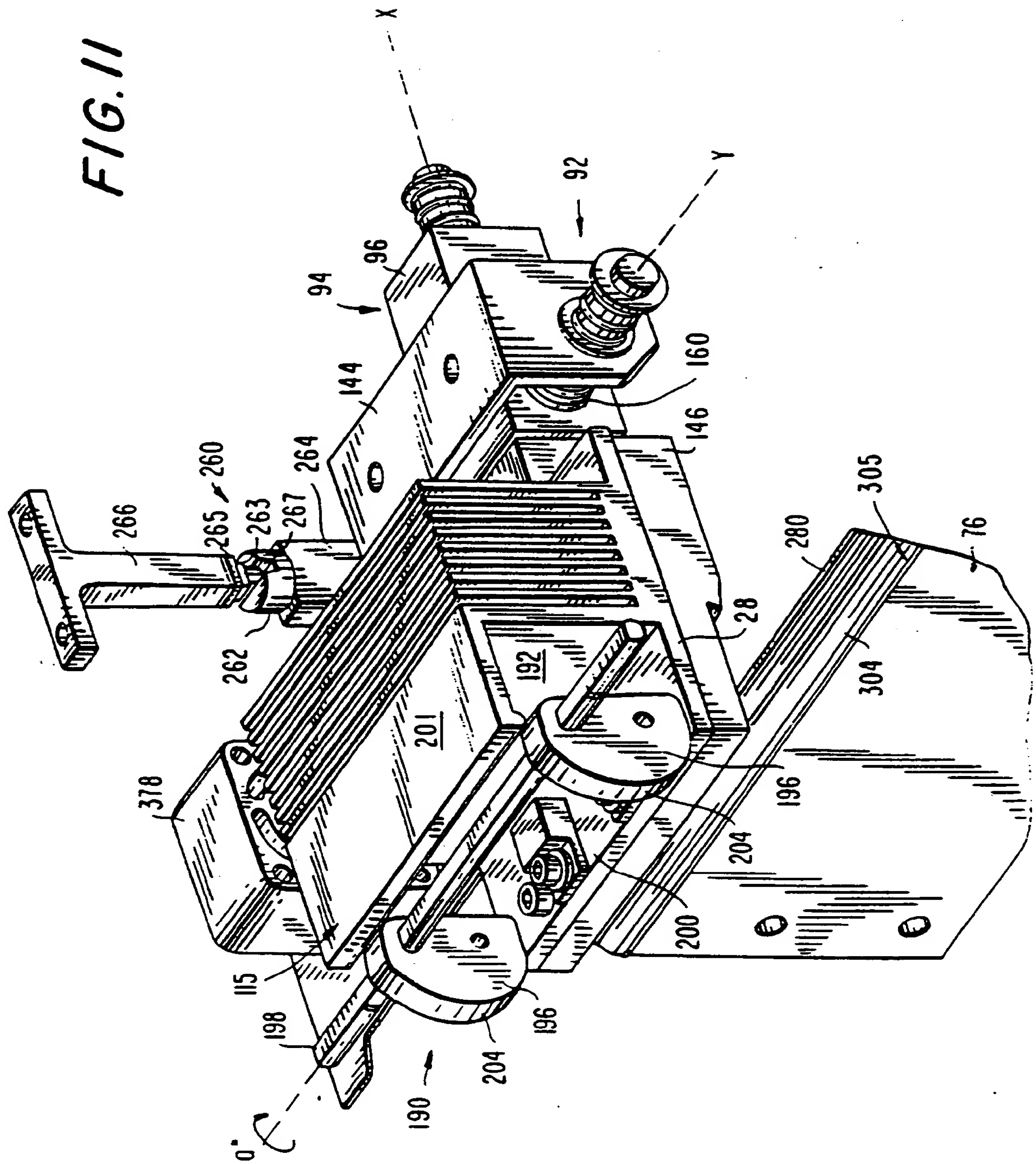

x
123
129
125
103
98
158
141
115
28
196
101
112
127
114
110
29
L
30
W
196
198
130
105
96
140
106
128
135
113
144
100
156
158
130
129
160
y
x
y

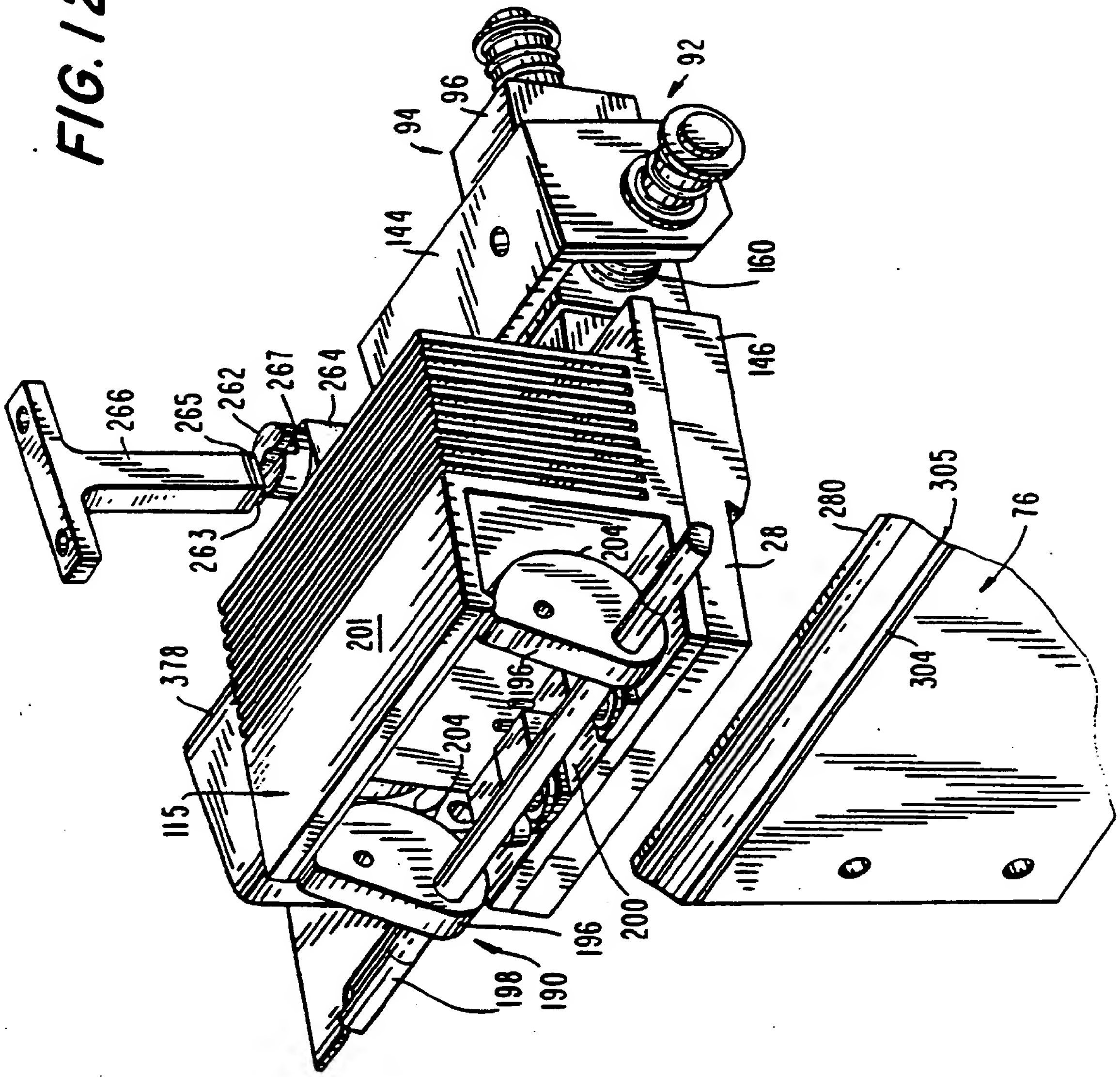
FIG.10

FIG. 11

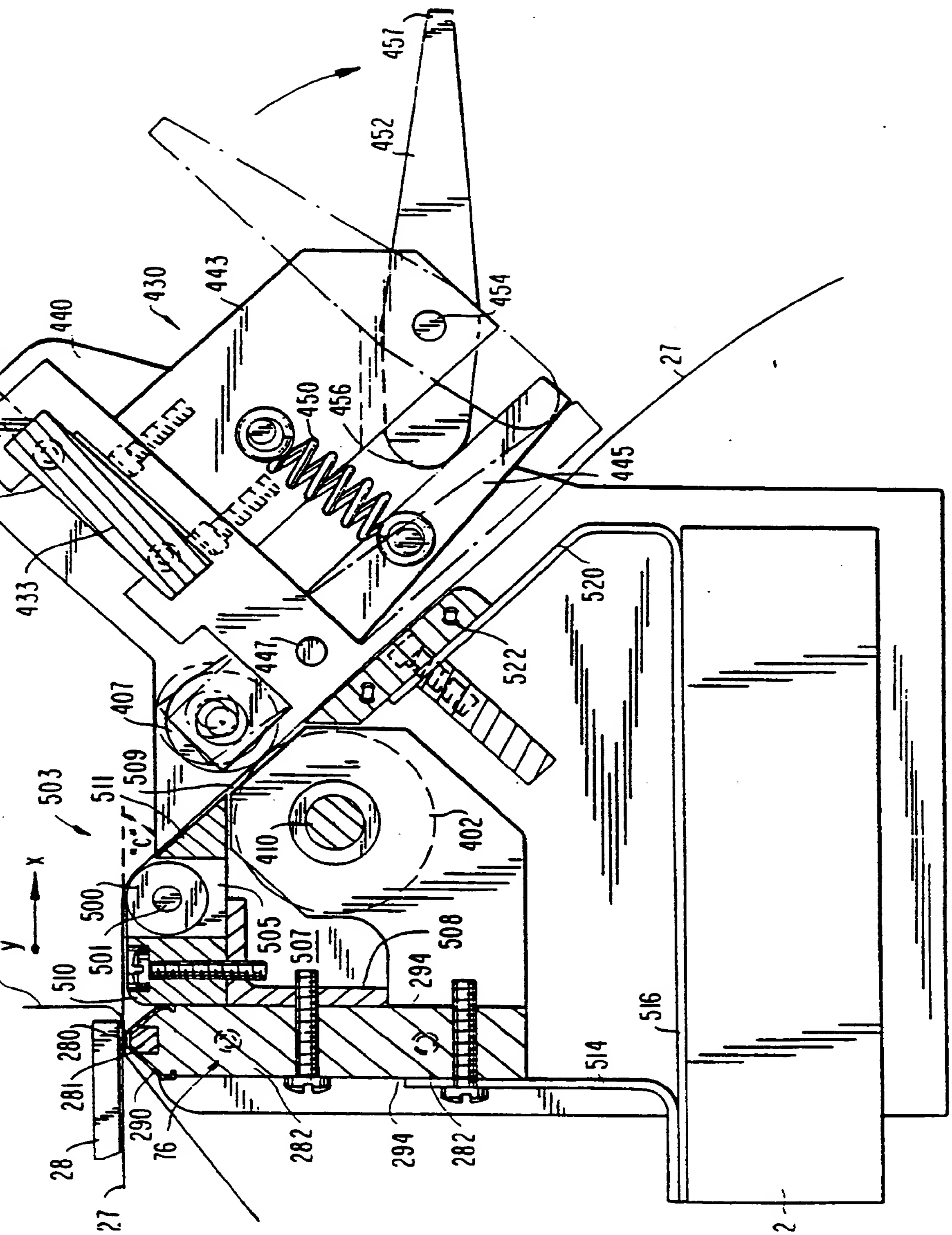


SUBSTITUTE SHEET

FIG. 12



SUBSTITUTE HEET



F/G. 13

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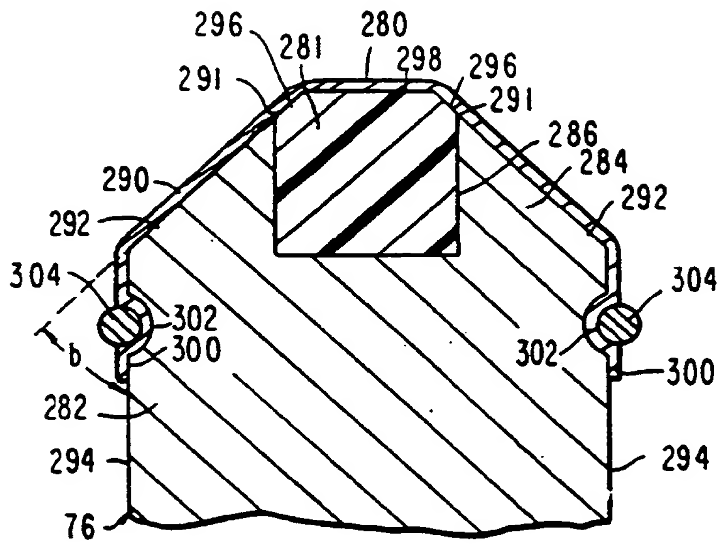


FIG.13A

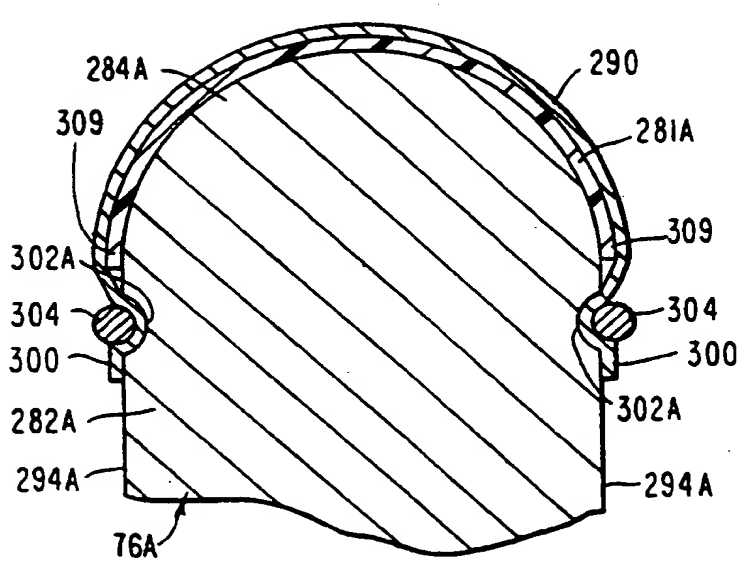


FIG.13B

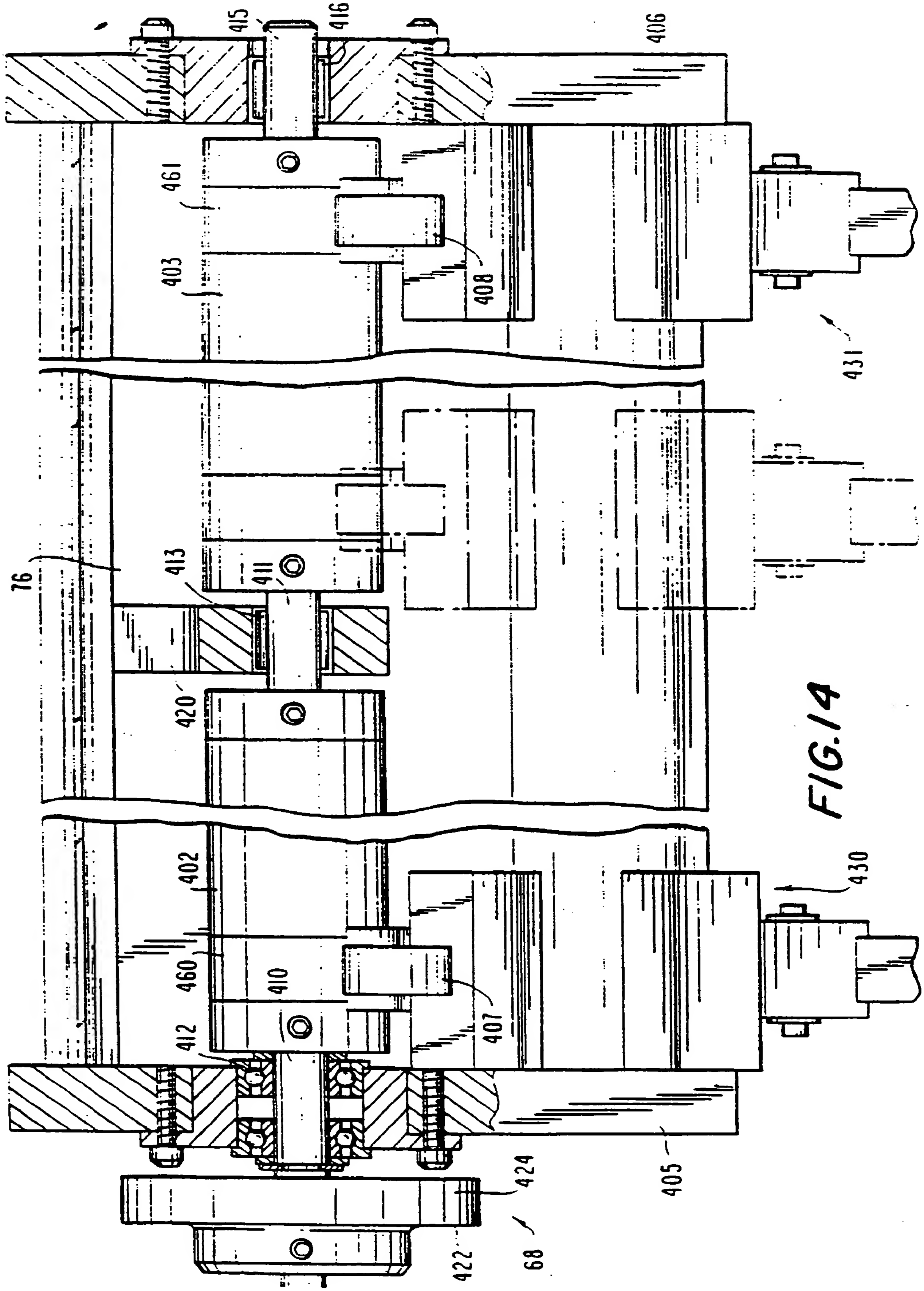


FIG.14

SUBSTITUTE SHEET

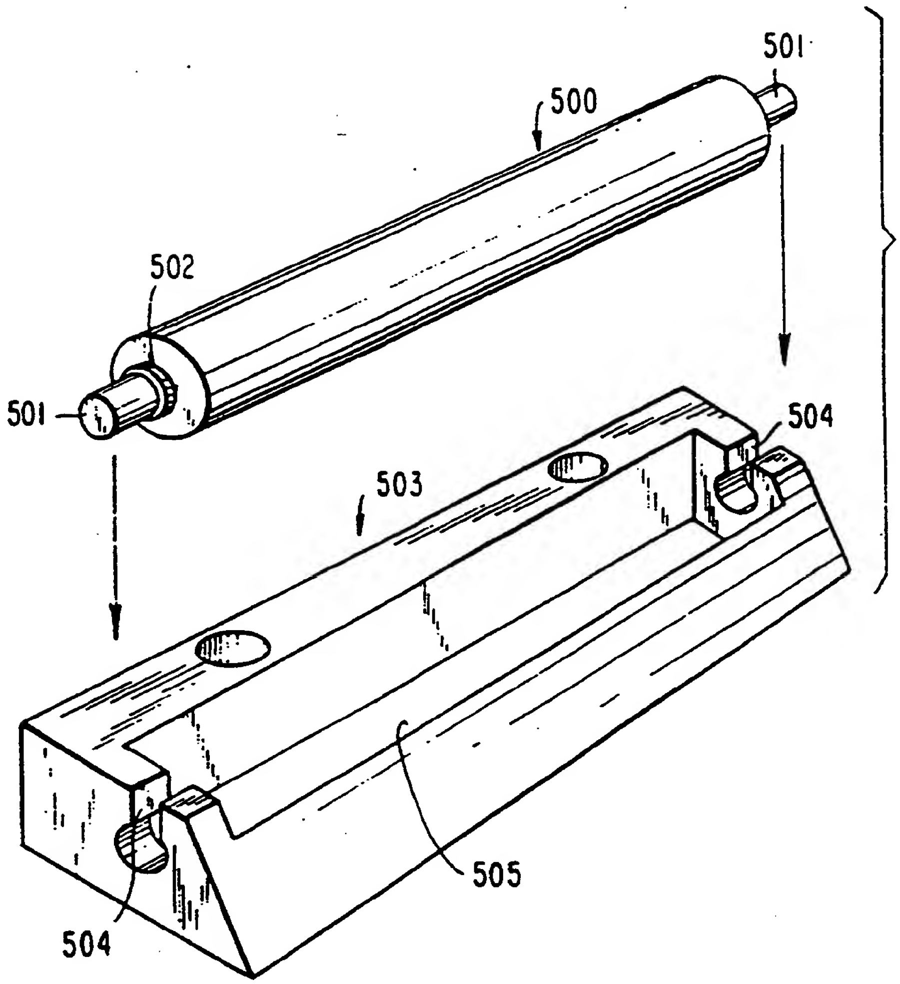
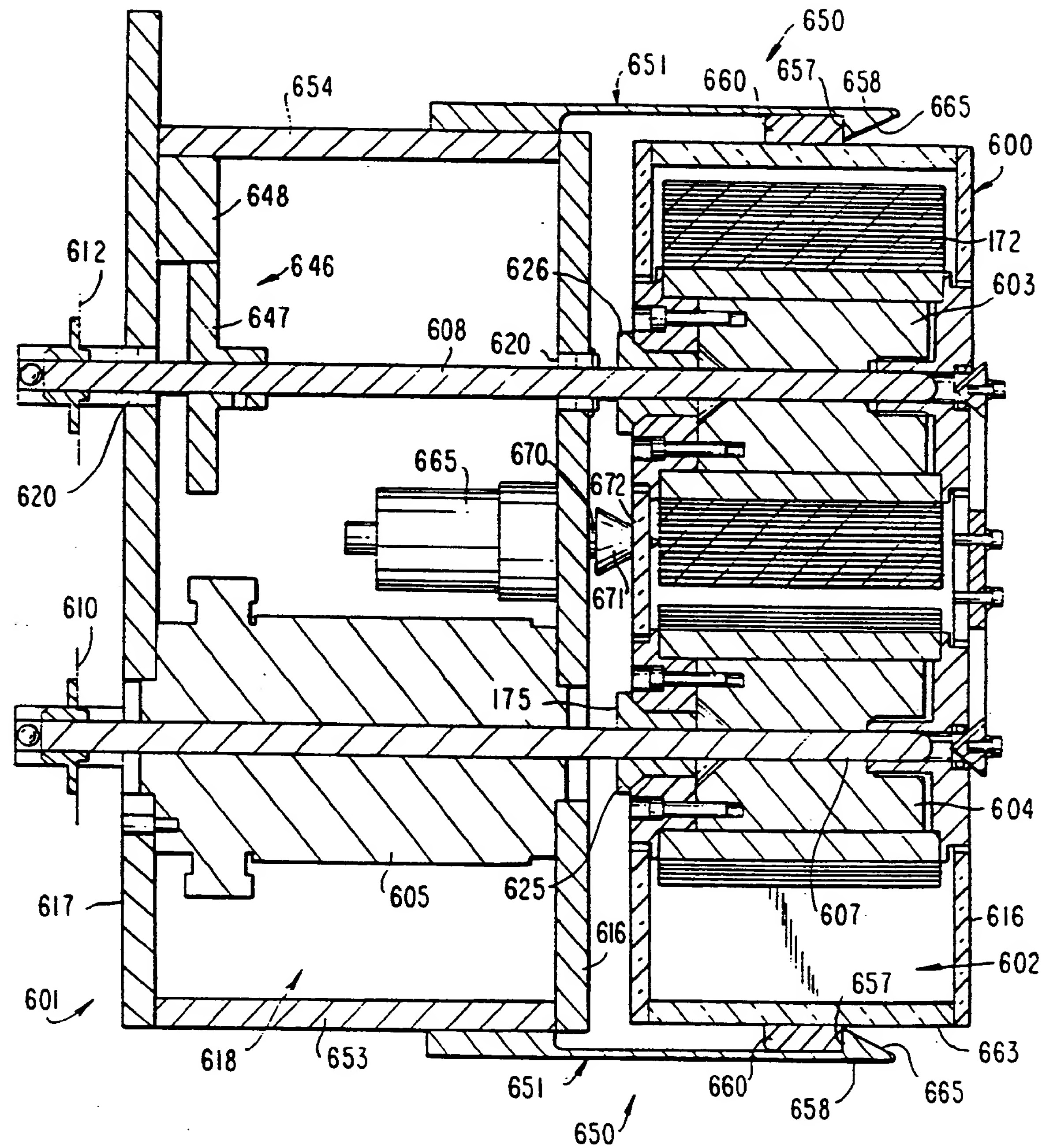


FIG. 15

FIG.16


650
651
660
657
658
665
600
654
648
172
612
646
626
603
647
608
620
665
670
672
620
671
610
175
604
617
605
625
607
616
616
602
657
601
618
653
651
660
658
665
663
650

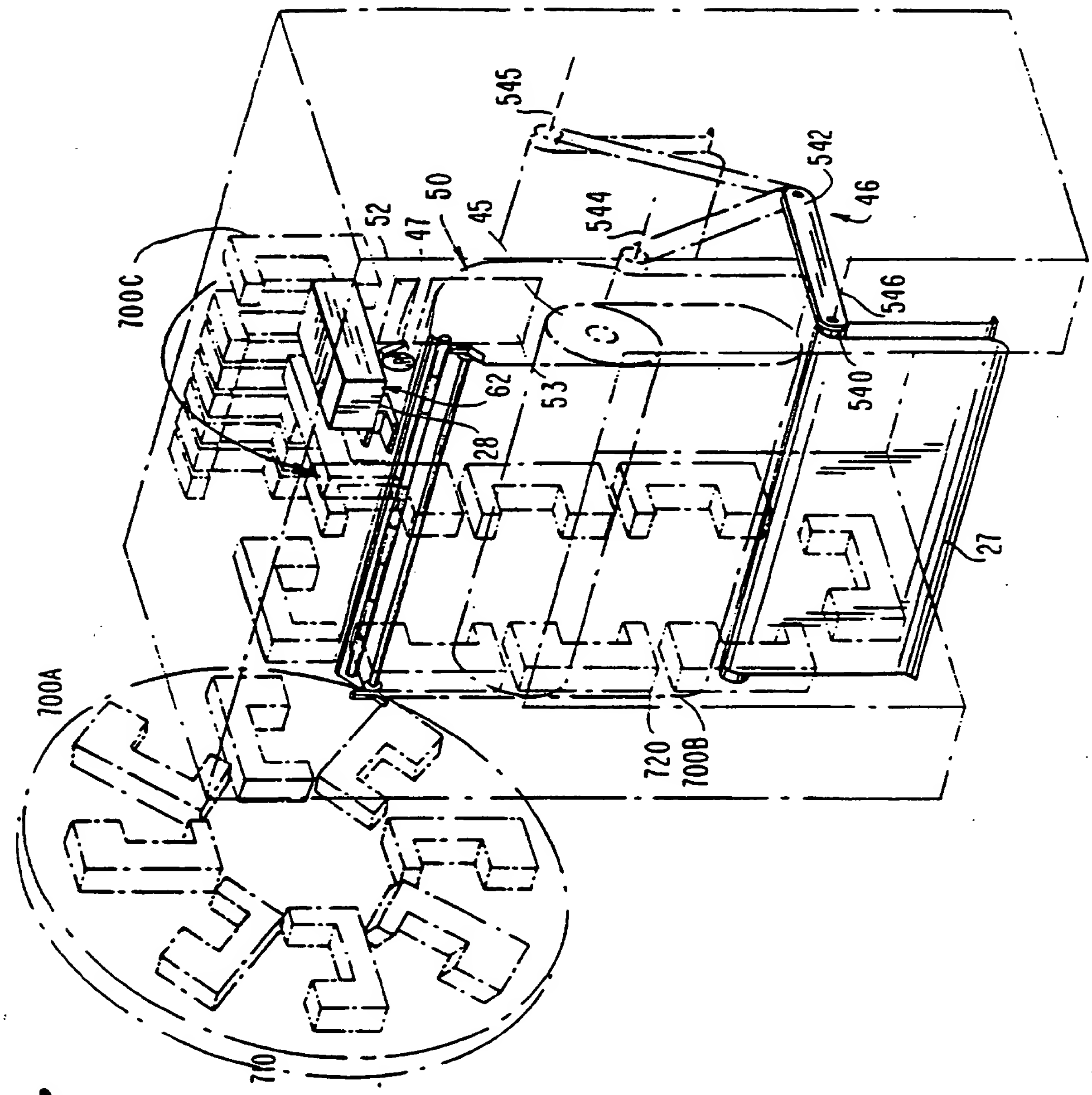

545
542
46
50
52
47
45
544
546
540
700C
62
53
28
27
700A
720
700B
710

FIG.17

FIG.18

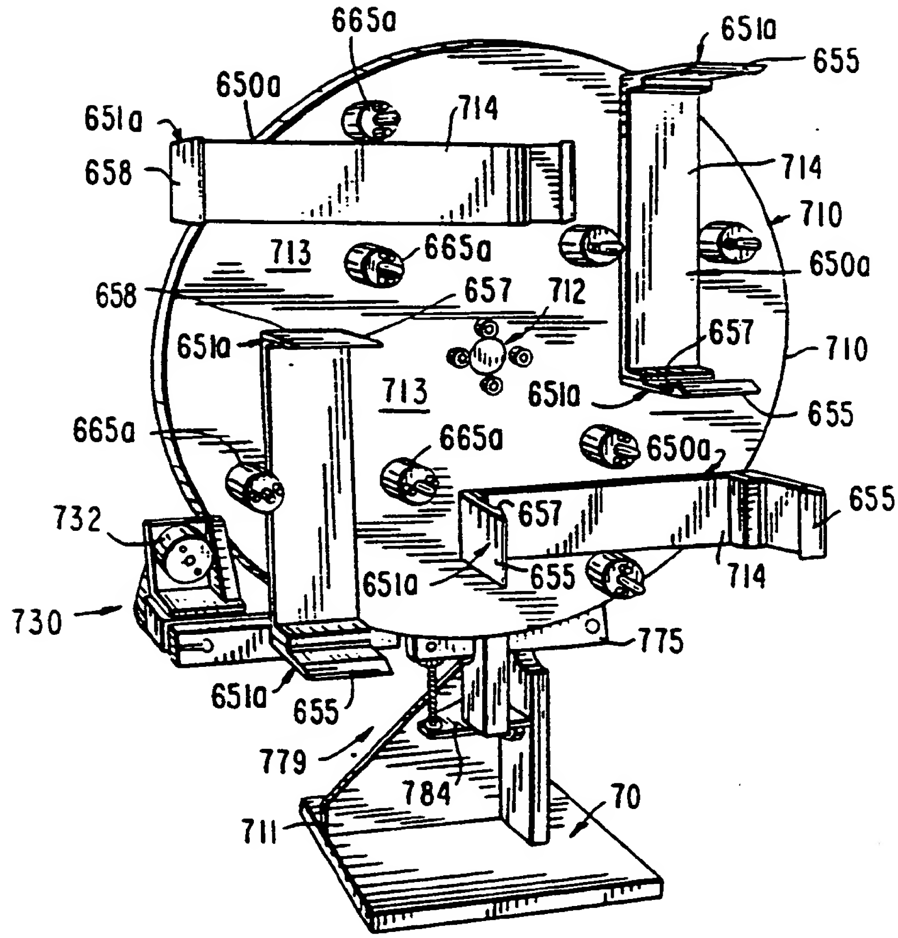
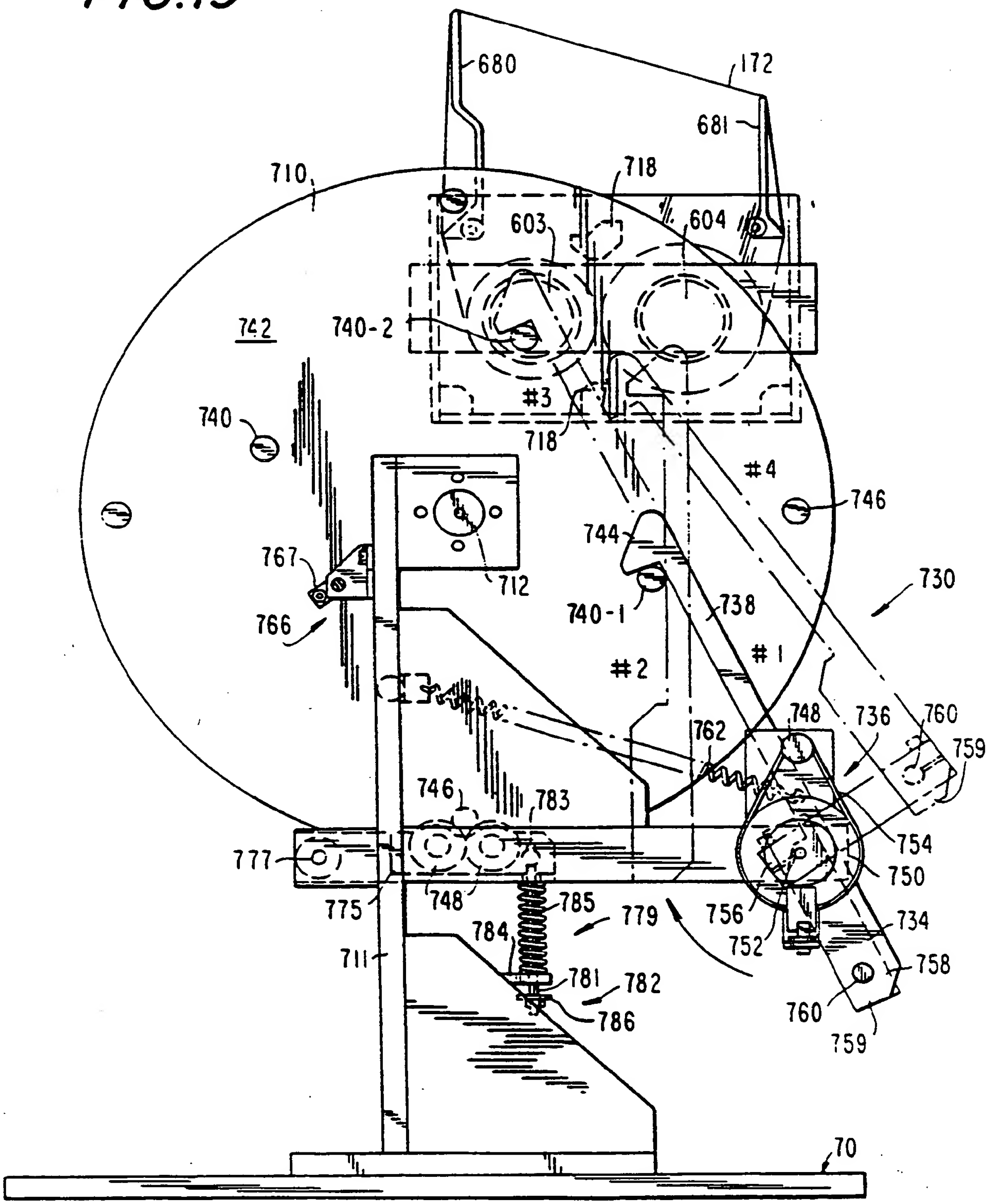

665a
651a
655
650a
651a
714
658
714
710
713
665a
650a
658
657
712
657
651a
710
713
651a
655
665a
665a
650a
657
655
732
651a
655
714
730
775
651a
655
779
784
70
711

FIG. 19



680
172
681
710
718
603
604
742
740-2
740
#3
718
#4
746
744
730
767
712
740-1
738
766
#1
#2
748
736
760
762
759
746
783
754
777
750
775
748
785
779
756
734
784
752
711
781
782
758
786
760
759
70

FIG. 20

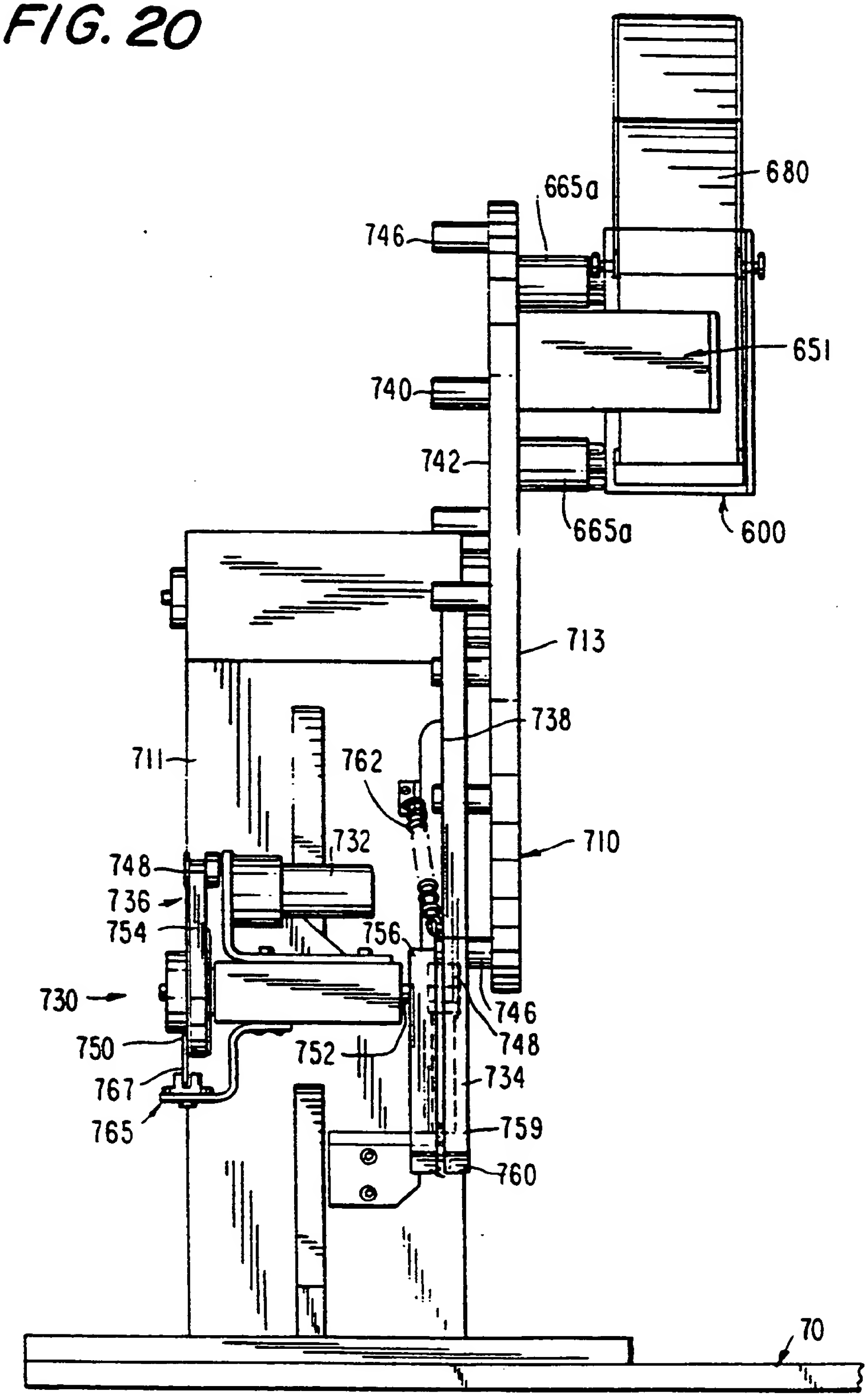

680
665a
746
651
740
742
665a
600
713
738
762
711
710
732
748
736
754
756
730
746
748
750
752
734
767
765
759
760
70

FIG. 21A

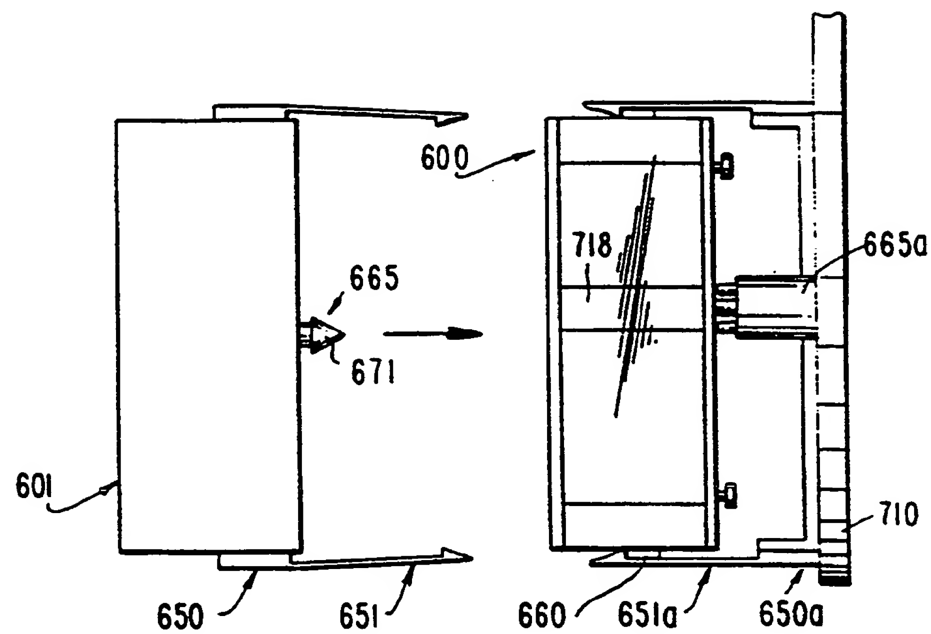
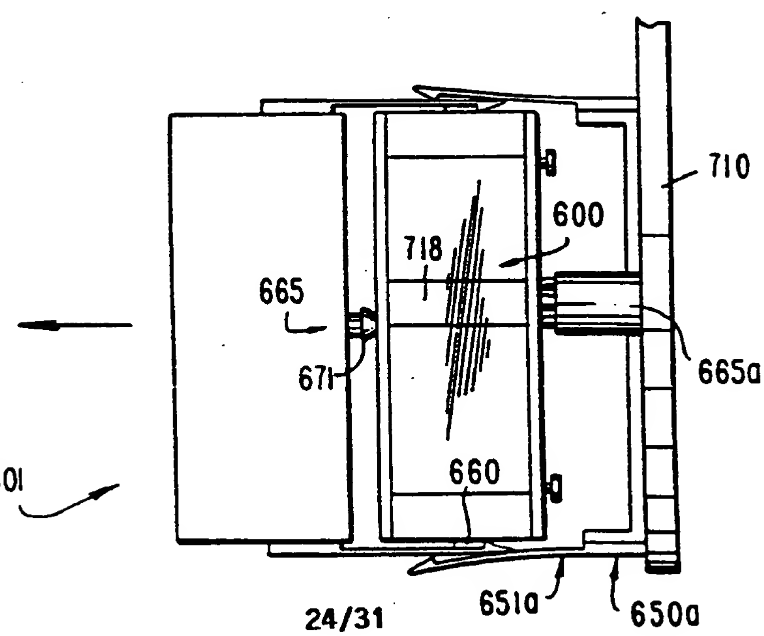


FIG. 21B



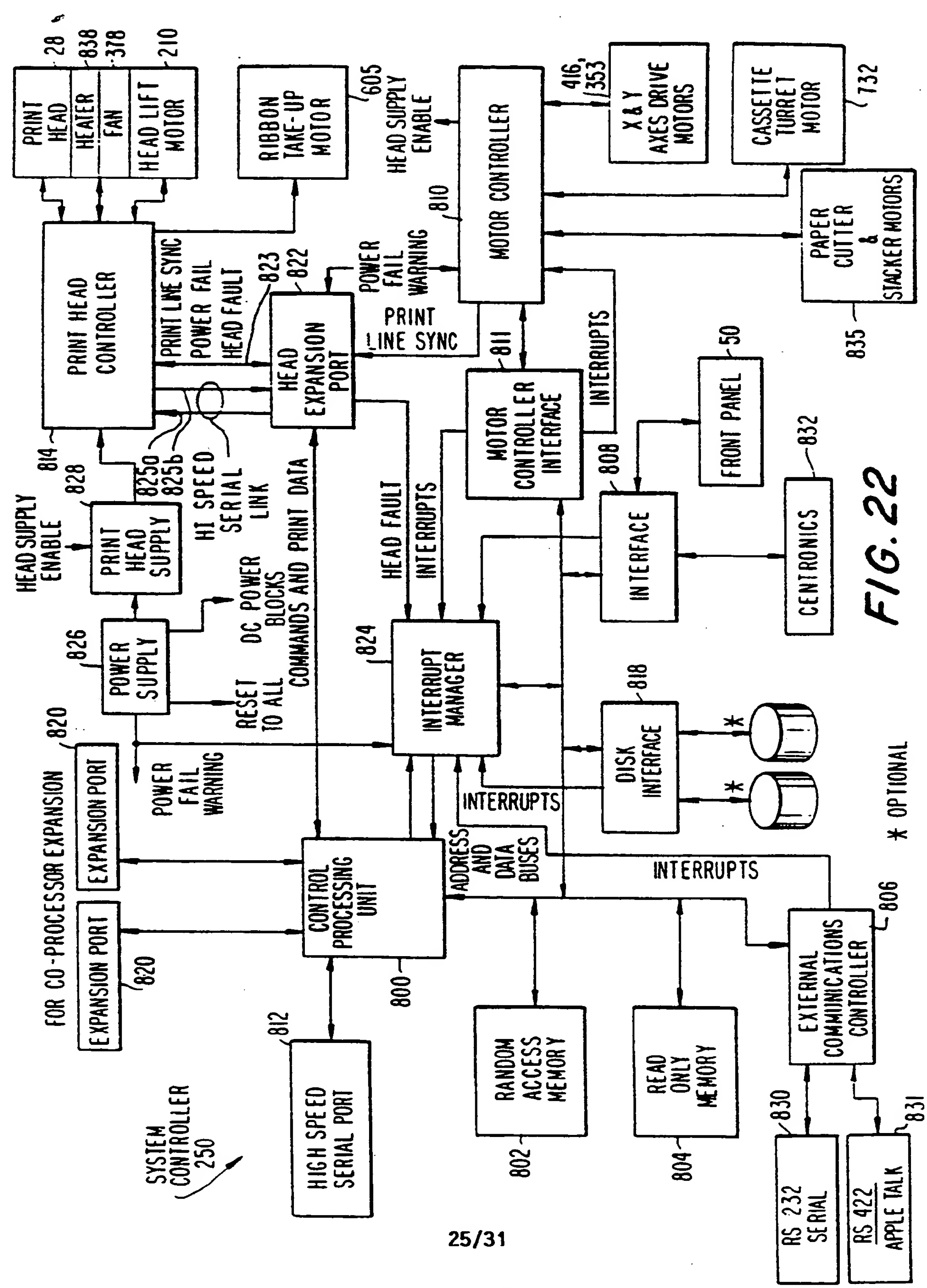

PRINT HEAD
HEATER
FAN
HEAD LIFT MOTOR
28
838
378
210
RIBBON TAKE-UP MOTOR
605
HEAD SUPPLY ENABLE
MOTOR CONTROLLER
810
416, 353
X & Y AXES DRIVE MOTORS
CASSETTE TURRET MOTOR
732
PAPER CUTTER & STACKER MOTORS
835
PRINT HEAD CONTROLLER
PRINT LINE SYNC
POWER FAIL
HEAD FAULT
823
822
POWER FAIL WARNING
PRINT LINE SYNC
HEAD EXPANSION PORT
811
INTERRUPTS
MOTOR CONTROLLER INTERFACE
FRONT PANEL
50
814
828
825a
825b
HI SPEED SERIAL LINK
HEAD SUPPLY ENABLE
PRINT HEAD SUPPLY
DC POWER BLOCKS
COMMANDS AND PRINT DATA
HEAD FAULT
INTERRUPTS
808
INTERFACE
832
CENTRONICS
826
POWER SUPPLY
RESET TO ALL
824
INTERRUPT MANAGER
818
DISK INTERFACE
820
FOR CO-PROCESSOR EXPANSION
EXPANSION PORT
POWER FAIL WARNING
INTERRUPTS
* OPTIONAL
ADDRESS AND DATA BUSES
INTERRUPTS
CONTROL PROCESSING UNIT
806
EXPANSION PORT
820
800
EXTERNAL COMMUNICATIONS CONTROLLER
812
RANDOM ACCESS MEMORY
READ ONLY MEMORY
830
831
SYSTEM CONTROLLER 250
HIGH SPEED SERIAL PORT
802
804
RS 232 SERIAL
RS 422 APPLE TALK

FIG. 22

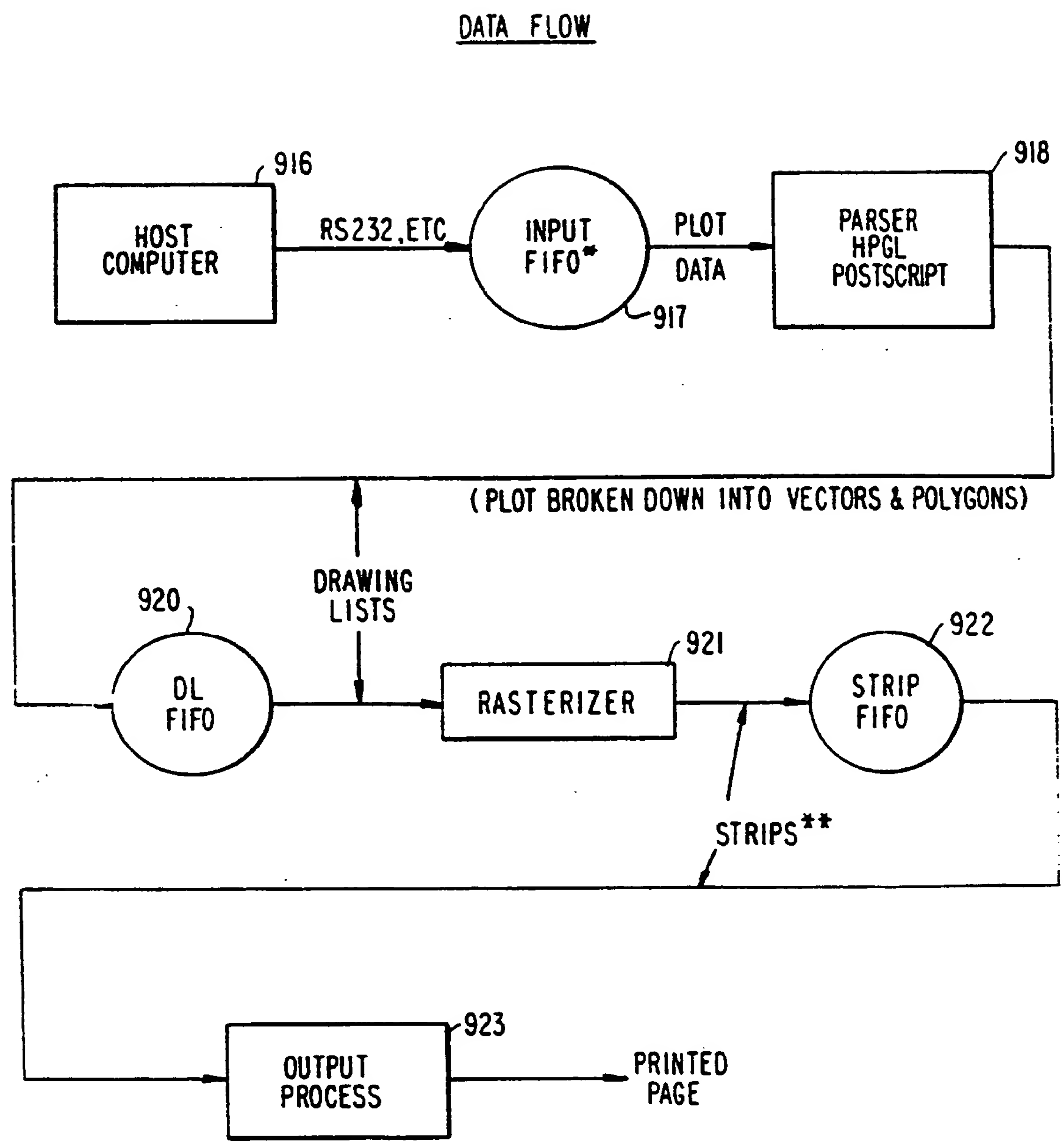

DATA FLOW
916
HOST COMPUTER
RS232, ETC
INPUT FIFO*
917
PLOT DATA
918
PARSER HPGL POSTSCRIPT
(PLOT BROKEN DOWN INTO VECTORS & POLYGONS)
DRAWING LISTS
920
DL FIFO
921
RASTERIZER
922
STRIP FIFO
STRIPS**
923
OUTPUT PROCESS
PRINTED PAGE

FIG. 23

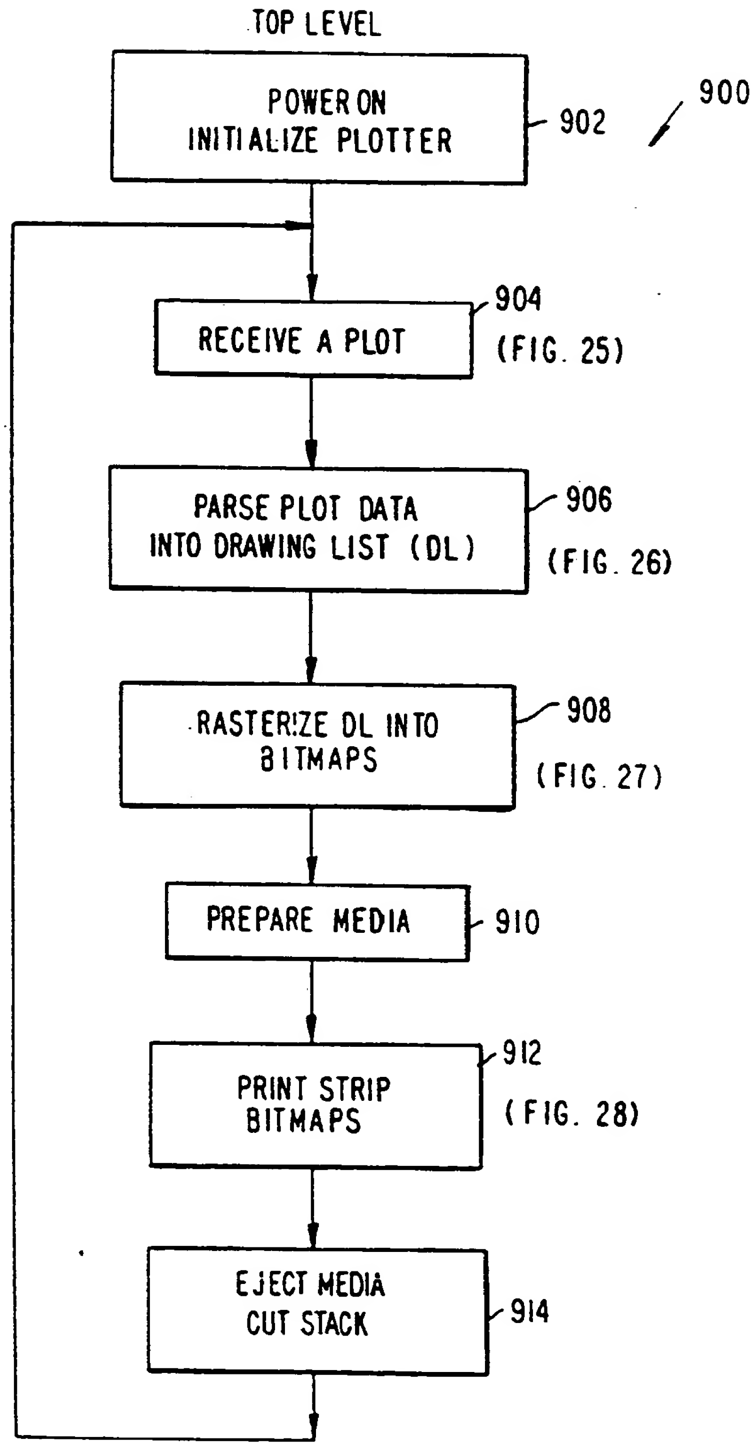

TOP LEVEL
POWER ON
INITIALIZE PLOTTER
902
900
RECEIVE A PLOT
904
(FIG. 25)
PARSE PLOT DATA
INTO DRAWING LIST (DL)
906
(FIG. 26)
RASTERIZE DL INTO
BITMAPS
908
(FIG. 27)
PREPARE MEDIA
910
PRINT STRIP
BITMAPS
912
(FIG. 28)
EJECT MEDIA
CUT STACK
914

FIG. 24

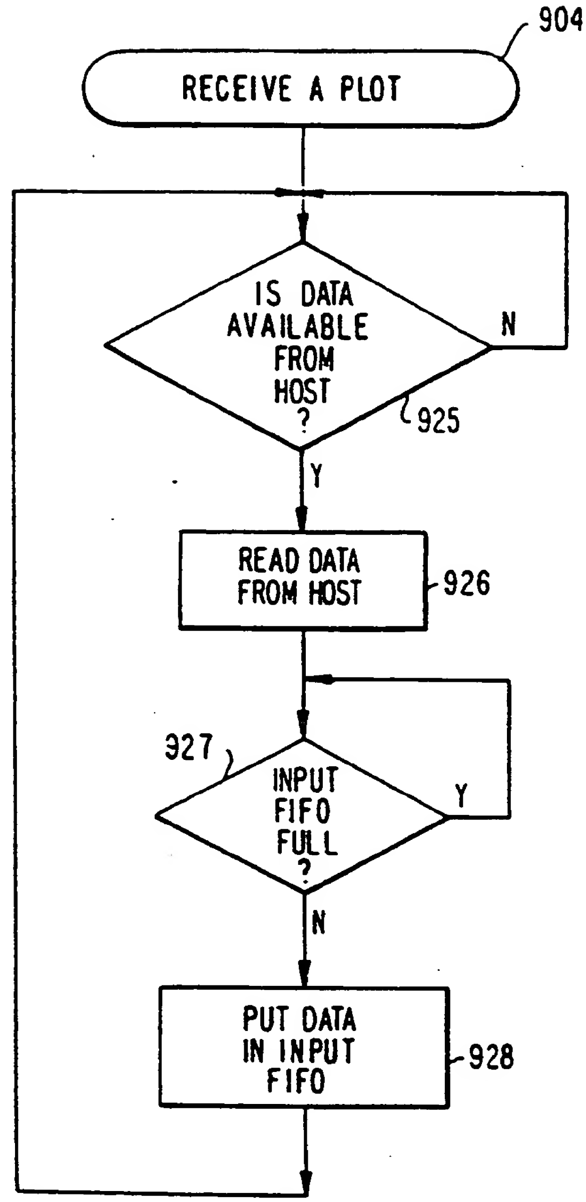

904
RECEIVE A PLOT
IS DATA AVAILABLE FROM HOST ?
N
925
Y
READ DATA FROM HOST
926
927
INPUT FIFO FULL ?
Y
N
PUT DATA IN INPUT FIFO
928

FIG. 25

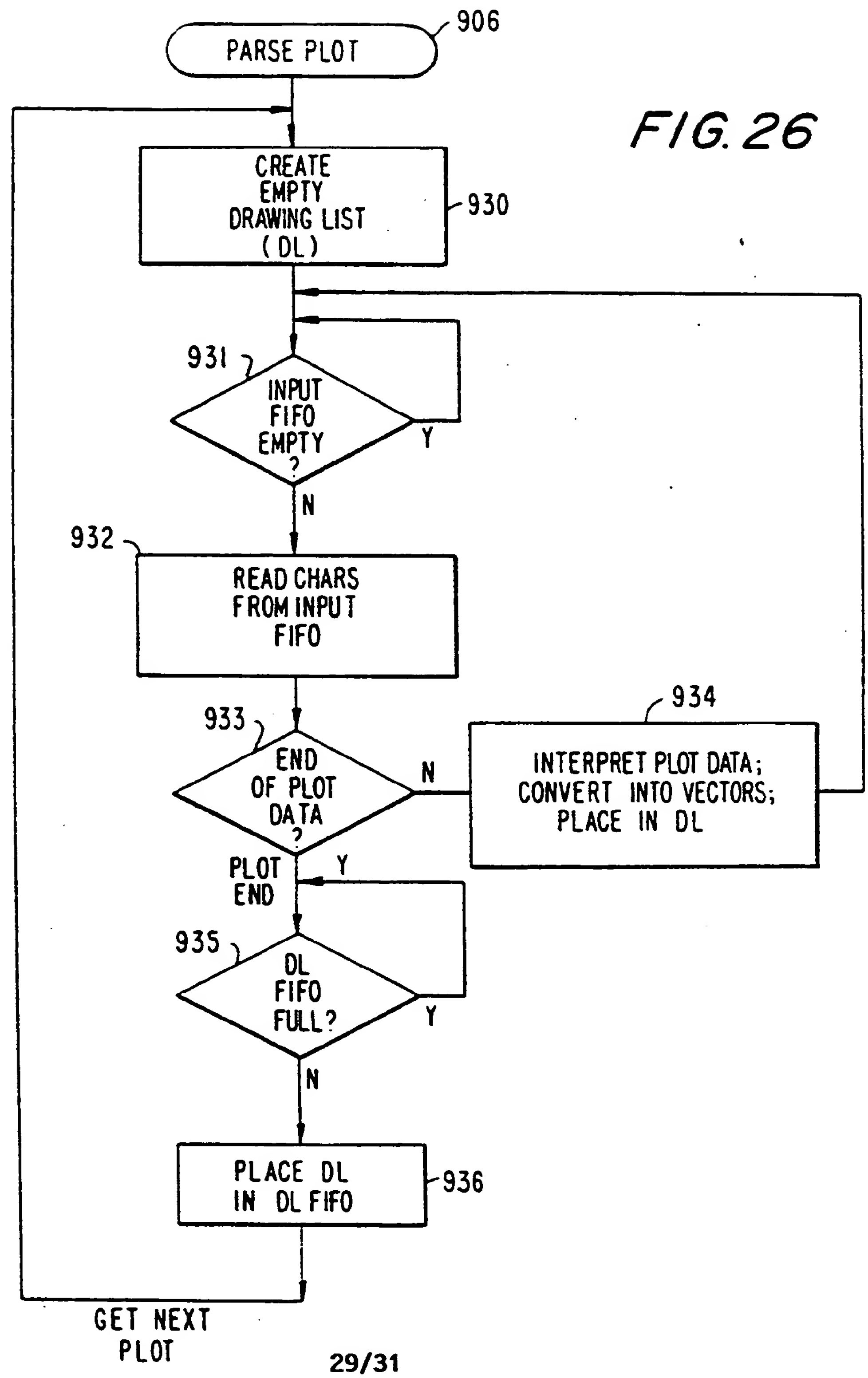
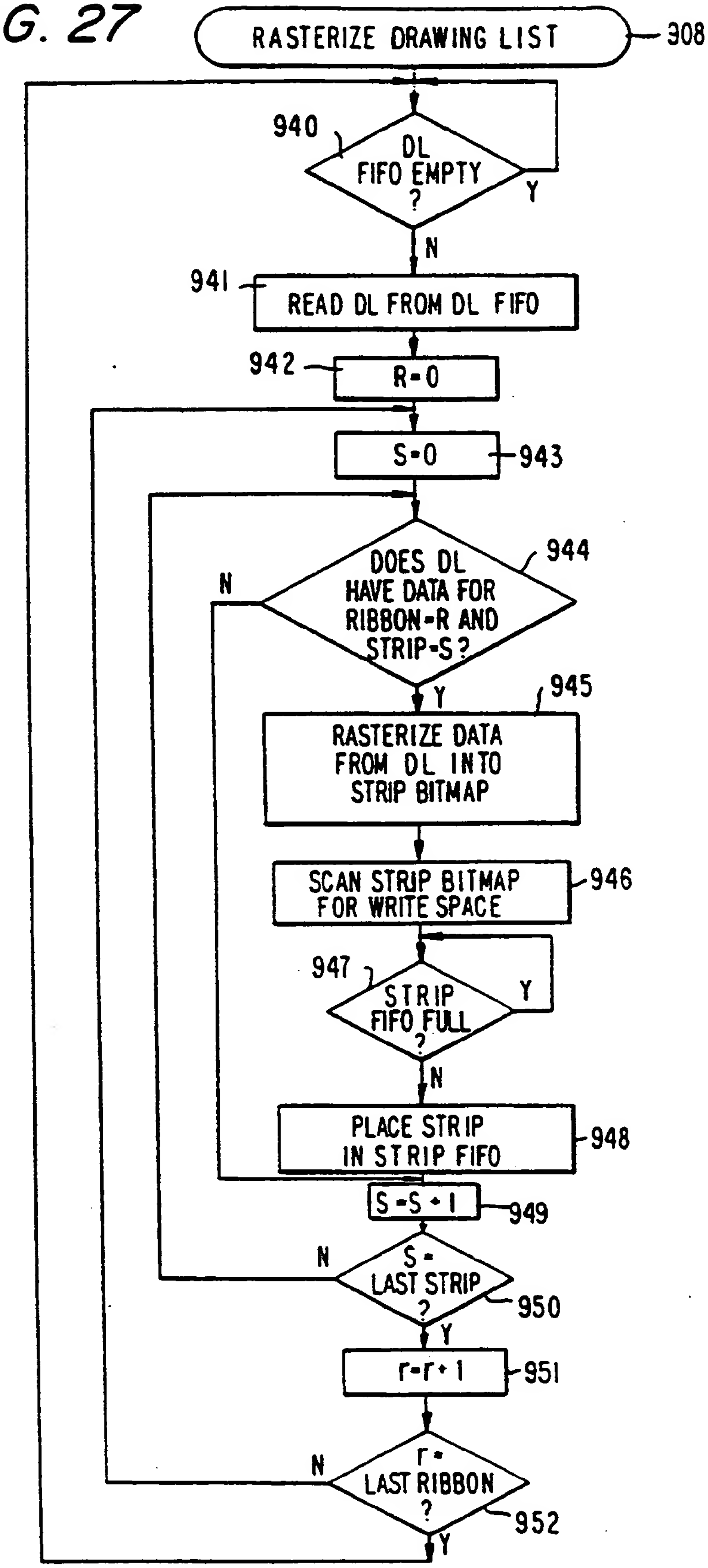

PARSE PLOT
906
CREATE EMPTY DRAWING LIST (DL)
930
931
INPUT FIFO EMPTY ?
Y
N
932
READ CHARS FROM INPUT FIFO
933
END OF PLOT DATA ?
N
934
INTERPRET PLOT DATA; CONVERT INTO VECTORS; PLACE IN DL
PLOT END
Y
935
DL FIFO FULL?
Y
N
PLACE DL IN DL FIFO
936
GET NEXT PLOT

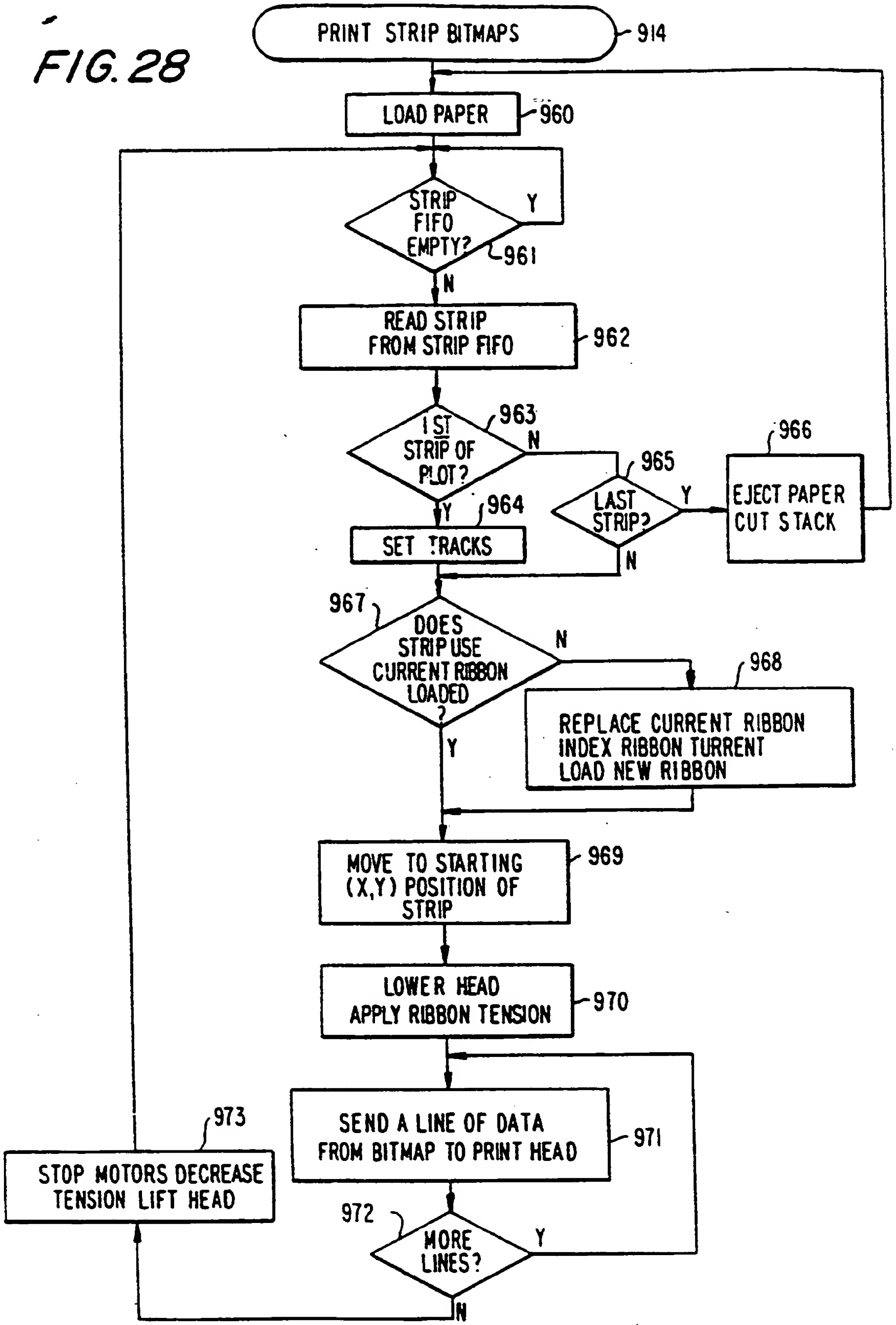
FIG. 26

FIG. 27



SUBSTITUTE SHEET

FIG. 28


PRINT STRIP BITMAPS
914
LOAD PAPER
960
STRIP FIFO EMPTY?
961
Y
N
READ STRIP FROM STRIP FIFO
962
1 ST STRIP OF PLOT?
963
N
Y
964
SET TRACKS
LAST STRIP?
965
Y
N
EJECT PAPER CUT STACK
966
967
DOES STRIP USE CURRENT RIBBON LOADED ?
N
Y
REPLACE CURRENT RIBBON
INDEX RIBBON TURRENT
LOAD NEW RIBBON
968
MOVE TO STARTING (X,Y) POSITION OF STRIP
969
LOWER HEAD
APPLY RIBBON TENSION
970
SEND A LINE OF DATA FROM BITMAP TO PRINT HEAD
971
972
MORE LINES?
Y
N
STOP MOTORS DECREASE TENSION LIFT HEAD
973

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US93/02726

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :B41J 25/304, 11/02, 11/04, 11/057, 11/08
US CL :346/139R,145,76PH,139D; 400/656,658,659,662,120
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 346/139R,145,76PH,139D; 400/656,658,659,662,120

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim N .
A	US,A, 4,946,297 (Koike et al.) 07 August 1990 See entirety	1-20

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be part of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date f mailing f the international search report
24 JUNE 1993	23 JUL 1993

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	HUAN TRAN Ngoc-Ho Nguyen NGUYEN NGOC-HO INTERNATIONAL DIVISION
Facsimile N . NOT APPLICABLE	Telephone No. (703) 308-0749